

# MONTHLY WEATHER REVIEW

Editor, EDGAR W. WOOLARD

VOL. 66, No. 11  
W. B. No. 1253

NOVEMBER 1938

CLOSED JANUARY 3, 1939  
ISSUED FEBRUARY 1939

## CLIMATIC RESEARCH IN THE SOIL CONSERVATION SERVICE

By C. W. THORNTHWAITTE, BENJAMIN HOLZMAN, and DAVID I. BLUMENSTOCK

[Soil Conservation Service, Washington, D. C., December 1938]

### INTRODUCTION

While accelerated soil erosion resulting from the misuse of land has been occurring in the United States since colonial days, it remained for the disastrous duststorms of the early 1930's, the acute agricultural problems in the Southeast, and the problems arising from overgrazing in the West to bring to the attention of the country as a whole the fact that soil has been and is being destroyed at an alarming rate. For some areas this realization has come almost too late. Thus, in such regions as the southeastern United States, the problem has become one not only of soil conservation but of soil regeneration as well.

The realization that soil erosion in the United States had become so serious that it could not be controlled by private or local agencies came at the time of an acute unemployment crisis and in 1933 led to the establishment of the Soil Erosion Service in the Department of the Interior to carry out those provisions of the National Industrial Recovery Act which related to the prevention of soil erosion.

For a number of years, research dealing with the problems of soil erosion had been carried on in a small way by certain State agricultural colleges, and by a few bureaus of the Department of Agriculture, notably Chemistry and Soils, Agricultural Engineering, Plant Industry, and the Forest Service. Several soil erosion experiment stations were being operated by the Bureau of Chemistry and Soils in cooperation with Agricultural Engineering. At these stations the research consisted primarily of controlled experimentation and involved the setting up of run-off plots to determine amounts of soil loss and run-off from slopes of various grade and length on different soil types and under different conditions of plant cover. These experiments were excellent demonstrations of the severity of erosion and were an important factor in arousing interest in the problem. The station research also included experimental work on the design of terraces and on erosion-resisting crop rotations and cropping practices.

It was recognized by the Secretary of the Interior that there was need for further research, and in response to his request to the Science Advisory Board in March 1934, the Land Use Committee of the Board engaged Prof. Carl O. Sauer of the University of California to prepare specific recommendations leading toward expansion of research. In a memorandum dated April 26, 1934, the Committee calls attention to the urgent need of undertaking as a unit research dealing with the relations of surface, soil, and climate to erosion.<sup>1</sup>

It had been recognized that soil erosion was inseparably related to land-use practices and could be controlled only through regulation of these practices. Consequently, in the spring of 1935 the Soil Erosion Service was transferred

from Interior to the Department of Agriculture. Shortly thereafter the Soil Conservation Service was established by act of Congress and soil-erosion activities of the various bureaus of the Department were consolidated within it.

In July 1935, pursuant to the recommendations of the Science Advisory Board, the section of Climatic and Physiographic Research was established. In developing this portion of the research program it was recognized that erosion is a geological process which is both normal and natural and which has been in operation since the first vapors condensed and fell upon the earth's surface. Although soil erosion is a relatively new process, being a consequence of man's misuse of the land, it is nevertheless a physiographic process initiated by the impact of climatic forces upon the earth's surface and is subject to the same physiographic principles as apply to erosion in general.

Experience has shown that it is neither possible nor desirable to separate erosion problems into a number of distinct minor problems which will conform to academic disciplines as we normally think of them. While it is necessary to invoke the aid of specialists, it is also necessary for such workers to transcend the limits of their own particular field, at least to the extent of being able to view and grasp the erosion problem as a whole.

For the climatologist, this has meant conducting his investigations with constant reference to experimental and field work. Climatic factors operating to produce erosion must actually be observed and studied in the field. In order to solve climatic problems presenting themselves in the field, existing climatic records must be examined and analyzed, additional data must be obtained wherever necessary, and where special problems demand the development of new techniques such must be devised. The ways in which these lines of approach have been utilized in the climatic work of the Soil Conservation Service constitutes the theme of this paper.

### THE ROLE OF CLIMATE

Climate may be regarded as operating in two ways in affecting the amount and nature of erosion. On the one hand, the mechanisms of erosion, such as sheet-wash, gully, mass-movement, and wind scour require water or wind for their operation and are also profoundly influenced by temperature conditions. The force with which these mechanisms operate is, in any given situation, directly related to climate. For example, generally speaking, the greater the amount of precipitation for any given time interval the greater will be the amount of erosion from running water. On the other hand, it is necessary to think of surface conditions—vegetation, soil, slope—as an integral part of the erosion complex, and to appreciate that similar storms will produce dissimilar erosion results in different regions because of variations in surface and cover. Under natural conditions the vegetation, soils, and land-forms of an area

<sup>1</sup>Sauer, Carl O., C. K. Leth, J. C. Merriam, and Isalah Bowman. Preliminary Recommendations of the Land-Use Committee Relating to Soil Erosion and Critical Land Margins. Science Advisory Board, Washington, D. C., 1934.

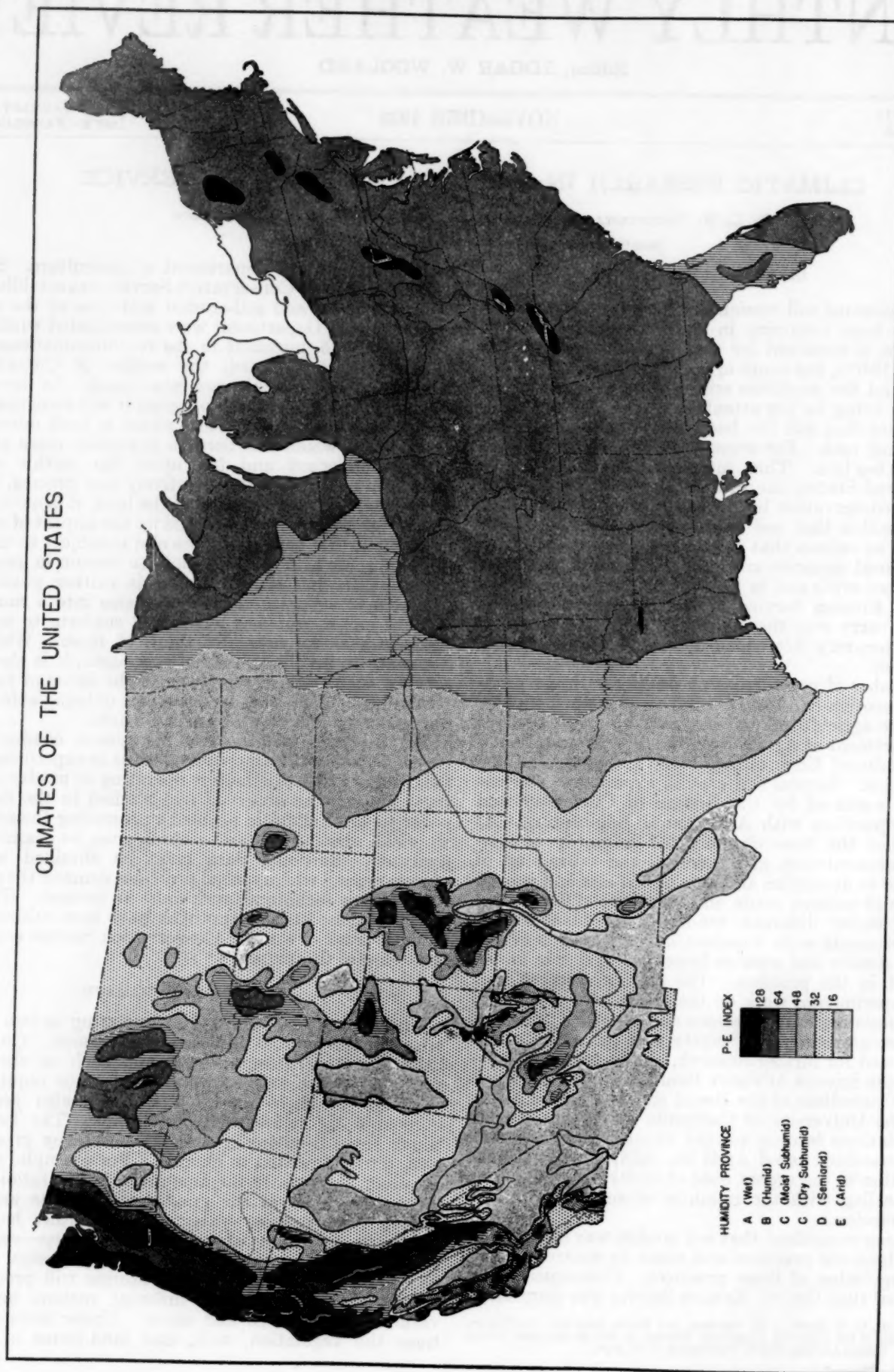


FIGURE 1.—Climates of the United States according to Thornthwaite's classification.

reflect to a large degree its climatic conditions; and even where man has engaged in farming, grazing, or lumbering, climatic influences on soil and slope and on the specific type of land utilization continue. The impact of climate, to a large extent, determines slope-soil-surface variations from region to region; and cannot be overlooked as a mode of approach to erosion problems.

#### CLIMATIC DELIMITATION OF EROSION REGIONS

In dealing with the climatic factors of erosion, the climatic classification has proved to be a useful tool. No classification of any body of knowledge is inherently right or wrong; rather it is more or less useful. In this instance it has been found that those climatic classifications that are oriented with specific reference to the distribution of natural vegetation and soils—such as those of Köppen<sup>2</sup> and Thornthwaite<sup>3</sup>—are of value in characterizing and differentiating natural regions (fig. 1). The areal coincidence of climatic, edaphic, and ecologic elements makes it possible to identify natural regions within which erosion problems are, in general, similar. Thus, the mesothermal humid area of the Southeastern United States is characterized by moderate to heavy precipitation, high rainfall intensities, long hot summers, short mild winters, heavy clay soils, and under natural conditions by forest vegetation. Because of high amounts and intensities of precipitation and because of the nature of the soil, the chief forms of erosion are gullying and sheet-wash. In the semiarid mesothermal southern Great Plains, wind erosion constitutes the chief hazard, and in the subhumid mesothermal summer-dry climate of California mass-movement assumes an important role. Similarly, the flood hazard is paramount in the humid microthermal region of New England, where snow melt contributes to the spring discharge of rivers.

Climatic classification has proved useful also for determining climatic risk to agriculture. In virtually all of the agricultural areas of the United States there have been occasional years when the climatic conditions were sufficiently adverse to cause total or partial crop failure. In some areas the climatic hazard is so great that crop failure is relatively frequent. If land abandonment does not result directly, it is brought about through crop failure as a consequence of soil depletion and wastage. By determining the type of climate that an area experiences during each year, or each season over a long period of years, the agricultural risk may be determined on an actuarial basis (figs. 2 and 3). Such information shows that some areas would profit by a change in crops or by reversion to grazing, and that other areas now being grazed should be allowed to return to their natural state. All such changes should be inaugurated before soil erosion becomes too severe and makes the land useless for any purpose whatsoever.

Especially care is required for land-use planning in climatic tension zones, such as the Great Plains, where the climate varies greatly from year to year. At Grant, Nebr., for example, the annual precipitation during the period of record ranged between a minimum of 9.47 inches in 1910 and a maximum of 35.84 inches in 1915. For the 17 scattered years, in which records are com-

plete, the climatic types (following Thornthwaite's classification) were as follows:<sup>4</sup>

Humid 1, Moist subhumid 4, Dry subhumid 6, Semi-arid 5, Arid 1. By obtaining such figures for the Great Plains and other critical regions the climatic risk can be determined. The works of Russell<sup>5</sup> and Thornthwaite<sup>6</sup> show that the determination of yearly climate serves as an effective basis for land-use planning.

It must be recognized that climatic risk analyses can be no better than the climatic classification on which they are based. Consequently, an important objective is to refine and readjust the method of classification so as to increase the value of contingent climatic risk studies. As long as climatologists appreciate the fact that such classifications are not an end in themselves, but rather convenient modes of synthesis, the need for this constant improvement will not be overlooked. In particular, when more satisfactory evaporation data are obtained, it will be possible to modify the Thornthwaite classification and render it more specifically applicable to erosion problems. This is one of the considerations that has stimulated the studies of evaporation being carried on at present and which will be discussed later.

#### SPECIFIC CLIMATIC FACTORS

Within a climatic region each climatic factor has its particular significance in the processes of soil erosion. The definitive recognition of these critical factors has been achieved by working inductively from field and laboratory information and by working deductively from a consideration of general physical principles. For example, one might reasonably assume that erosion amount is directly related to rainfall intensity. Actually, field experience has demonstrated that such a simplistic view of the problem is not justified. Research in the Piedmont area of South Carolina indicates that intense local showers are chiefly responsible for gullying and sheet wash while the gentle, long continuing general rains cause gully-caving and filling.<sup>7</sup> Lighter rainfalls tend to induce mass-movement as contrasted with more spectacular cutting or sluicing caused by rains of high intensity. This relationship between rainfall intensity and soil erosion involves type and extent as well as amount of erosion.

The climatologist dealing with the practical solution of the erosion problem cannot be satisfied with working merely in terms of "rainfall amounts." Precipitation components such as storm duration, area, and frequency require consideration similar to that accorded rainfall intensity. Likewise, the temperature factor must be analyzed in detail. The number of times the freezing point is crossed together with prevailing soil moisture conditions are of critical significance because of their bearing on weathering and frost action. Temperature relationships as they affect snow accumulation and melting are important in any consideration of flood and run-off problems. Wind velocity is still another critical climatic element. It is necessary to compare seasonal variations in velocity with the crop calendar in order to determine whether velocities are sufficiently high to constitute a hazard at those times of the year when the fields are plowed or left fallow.

<sup>2</sup> Köppen, Wladimir. Versuch einer Klassifikation der Klimate, vorzugsweise nach ihren Beziehungen zur Pflanzenwelt. Geogr. Zeitschr., Vol. 6, pp. 593-611, 657-679, 1900; idem. Klassifikation der Klimate nach Temperatur, Niederschlag und Jahreslauf, Petermanns Mitt., Vol. 64, pp. 193-203, 243-248, 1918; idem. Die Klimate der Erde, Berlin und Leipzig, 1923. A new classification appears in Köppen-Geiger, Klimakarte der Erde (1:20,000,000), Justus Perthes, Gotha, 1928.

<sup>3</sup> Thornthwaite, C. Warren. The Climates of North America According to a New Classification. Geogr. Rev., Vol. XXI, No. 4, pp. 633-655, October 1931; idem. The Climates of the Earth. Geogr. Rev., Vol. XXIII, No. 3, pp. 433-440, July 1933.

<sup>4</sup> Thornthwaite, C. Warren. The Significance of Climatic Studies in Agricultural Research. Soil Sci. Soc. America, Proc., vol. 1, pp. 475-480, 1937.

<sup>5</sup> Russell, Richard Joel. Climatic Years. Geogr. Rev., vol. XXIV, No. 1, pp. 92-103, January 1934.

<sup>6</sup> Thornthwaite, C. Warren. The Great Plains. Chapter V in Migration and Economic Opportunity, Univ. Pa. Press, pp. 202-250, 1936.

<sup>7</sup> Ireland, H. Andrew, C. F. Stewart Sharpe, and D. Hoye Eargle. Principles of Gully Erosion in the Piedmont of South Carolina. U. S. D. A. Tech. Bull. No. 653, 1936.

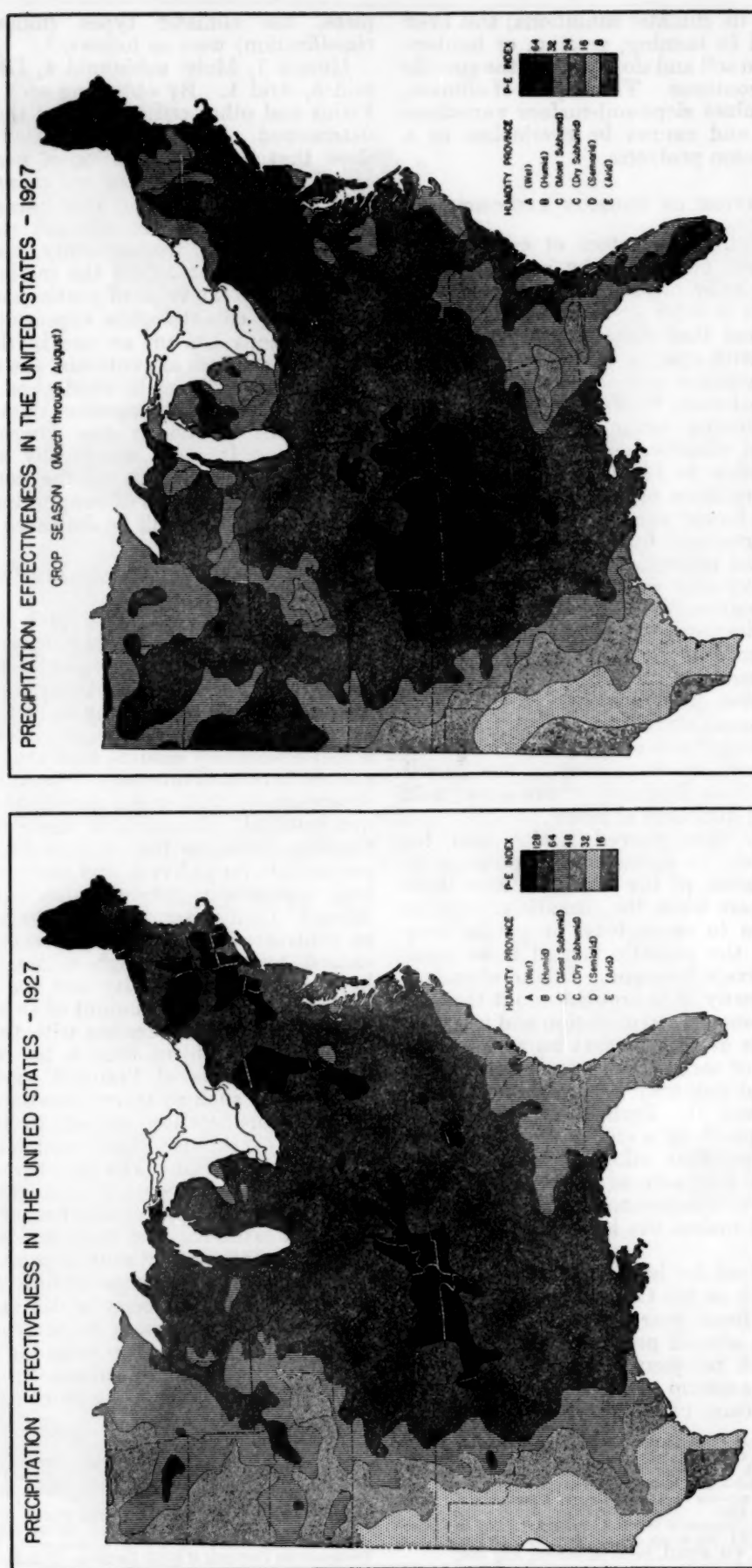


FIGURE 2.—Precipitation effectiveness for the year and the crop season of 1927 according to Thornthwaite's classification.

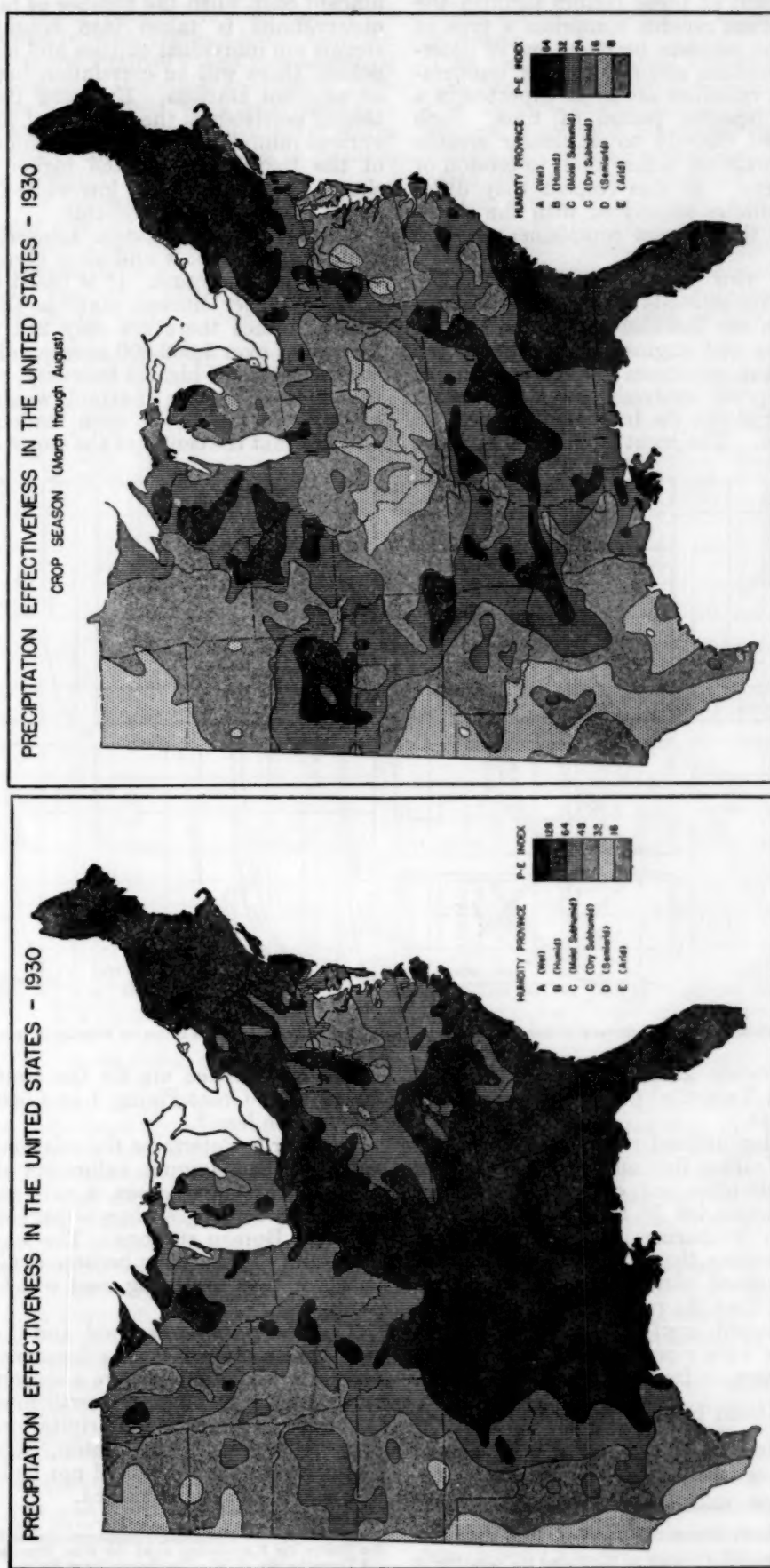


FIGURE 3.—Precipitation effectiveness for the year and the crop season of 1930 according to Thornthwaite's classification.

The statistical treatment of these factors through the analysis of Weather Bureau records comprises a type of climatic risk study. The problem becomes one of determining what rainfall intensities, storm durations, temperature variations, or wind velocities are to be expected in a given region during a specific period of time. Such investigations are related directly to particular erosion processes and land-use practices rather than to erosion or land utilization in general. In this respect they differ from the climatic risk studies associated with the classification of climates, but the two are complementary and integrally related.

Unfortunately, only two specific climatic factors, rainfall intensity and storm amounts of precipitation, have been treated in detail in the literature of climatology or hydrology. Hydrologists and engineers, faced with the necessity of estimating the maximum storage capacity of their reservoirs or disposal systems, have developed various methods of determining the frequency of specified amounts of precipitation. The most important of these

nificant only when the number of random or independent observations is taken into consideration. Since rainstorms are individual entities and affect areas, not merely points, there will be correlation between rainfall records at adjacent stations. By using Bartels'<sup>11</sup> technique for testing persistence, the amount of correlation between the various rainfall records was determined, and the reliability of the frequencies for the higher storm amounts was shown to be exceedingly low while that for the maximum storm is completely unreliable.

Yarnell's study presents intensity-frequency data for short time intervals and thus gives particular emphasis to local intense rains. It is based on records from first-order Weather Bureau stations throughout the United States. Since there are only 211 such stations serving an area of over 3,000,000 square miles, it is clear that the storm centers of highest intensity, which are rarely more than 25 square miles in extent, would in the vast majority of cases be missed by such inadequate sampling. The chances that the center of the storm of maximum intensity

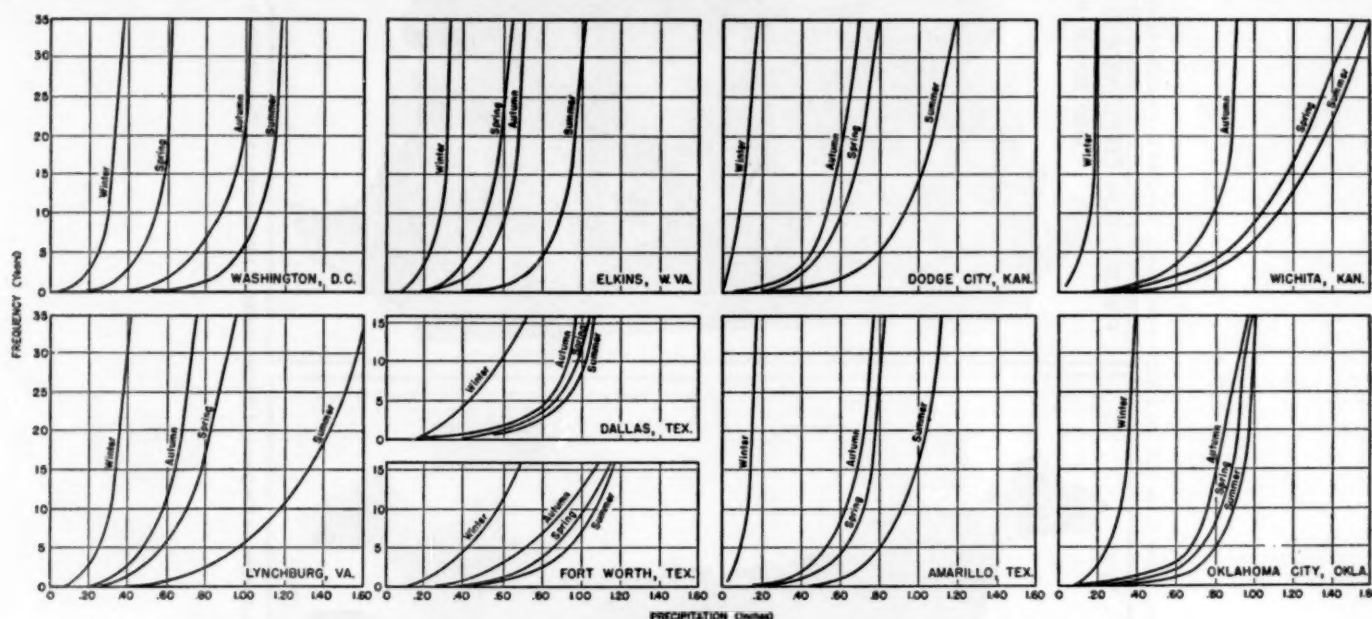


FIGURE 4.—Intensity-frequency curves of 15-minute amounts of precipitation by seasons for nine first-order Weather Bureau stations.

are the Miami Conservancy District's study of storm amounts of rainfall<sup>8</sup> and Yarnell's<sup>9</sup> publication, "Rainfall Intensity-Frequency Data."

The Miami investigation utilized records from all first-order and cooperative Weather Bureau stations east of the one hundred and third meridian and, dividing the eastern United States into quadrangles 2° square, applied the station-year method in preparing expectancy figures. In brief, this method assumes that if there are  $x$  stations in a given area of assumed climatic uniformity, each having  $y$  years of record, then the product  $xy$  may be used as a total aggregate record applying to any point in the area. Thus, if there were  $z$  occurrences of any given rainfall intensity in the area its frequency would be stated as  $\frac{xy}{z}$  years. Clarke-Hafstad has shown that the results obtained by this statistical technique are not as reliable as has heretofore been assumed.<sup>10</sup> The results are sig-

would be recorded are for the United States about 1 in 600, for the Great Plains, 1 in 1,000, and for the western States even less.<sup>12</sup>

In order to determine the relation of Yarnell's observed values to the maximum values not observed it is necessary to have, in sample areas, a very much closer spacing of automatic raingages than is provided by the first-order Weather Bureau stations. The way in which the necessary rainfall data have become available and the manner in which they are being used will be discussed in a later paragraph.

The station-year method and Yarnell's method both give only annual intensity-frequency data. In soil conservation operations, where a seasonal rhythm of farming operations and of plant growth must be considered, it is necessary to know how precipitation intensity-frequencies vary from season to season. Under successful farm management the soil would not be left exposed to erosion in a season of serious hazard.

<sup>8</sup> Miami Conservancy District. Storm Rainfall of Eastern United States (Revised). Dayton, 1936.

<sup>9</sup> Yarnell, David L. Rainfall Intensity-Frequency Data. U. S. Dept. Agriculture Misc. Pub. No. 204, 1934.

<sup>10</sup> Clarke-Hafstad, Katharine. A Statistical Method for Estimating the Reliability of the Station-Year Rainfall Record. Trans. A. G. U., 1938.

<sup>11</sup> Bartels, J. Zur Morphologie Geophysikalischer Zeitfunktionen. Sonderang. aus den Sitzber. der Preussischen Akad. der Wiss. Phys. Math. Klasse. Vol. 90, 1935.

<sup>12</sup> Thornthwaite, C. W. The Reliability of Rainfall Intensity-Frequency Determinations. Trans. A. G. U., 1937.

A recent study<sup>13</sup> utilizing detailed rainfall data from three eastern stations and from six stations in the southern Great Plains and southern Prairies<sup>14</sup> has demonstrated the practical value of detailed statistical analyses of individual climatic factors. The data were analyzed with regard to seasonal variations in rainfall intensity, storm duration, storm frequency, diurnal variations in rainfall, and length of rainless periods.

Rainfall intensities are highest during the summer and lowest during the winter due to the predominance of convective precipitation during the summer and of warm front, cyclonic precipitation during the winter. In the eastern Piedmont and mountain section, autumn and spring intensities are of equal order of magnitude; while

where spring is the season having the maximum number of storms.

An analysis of diurnal variation in rainfall shows a summer afternoon maximum associated with thermal convective showers at the eastern stations, whereas there is a summer nighttime maximum in the prairies area. Although the summer nighttime maximum has been recognized for some time<sup>15</sup> detailed study of the diurnal variation in amount, frequency, and intensity of rainfall has suggested for the first time a number of climatic problems that are both directly and indirectly related to soil conservation problems. Not only do rains fall during periods of darkness when the evaporation rate is low, but also the intensity of precipitation usually is less than that occurring

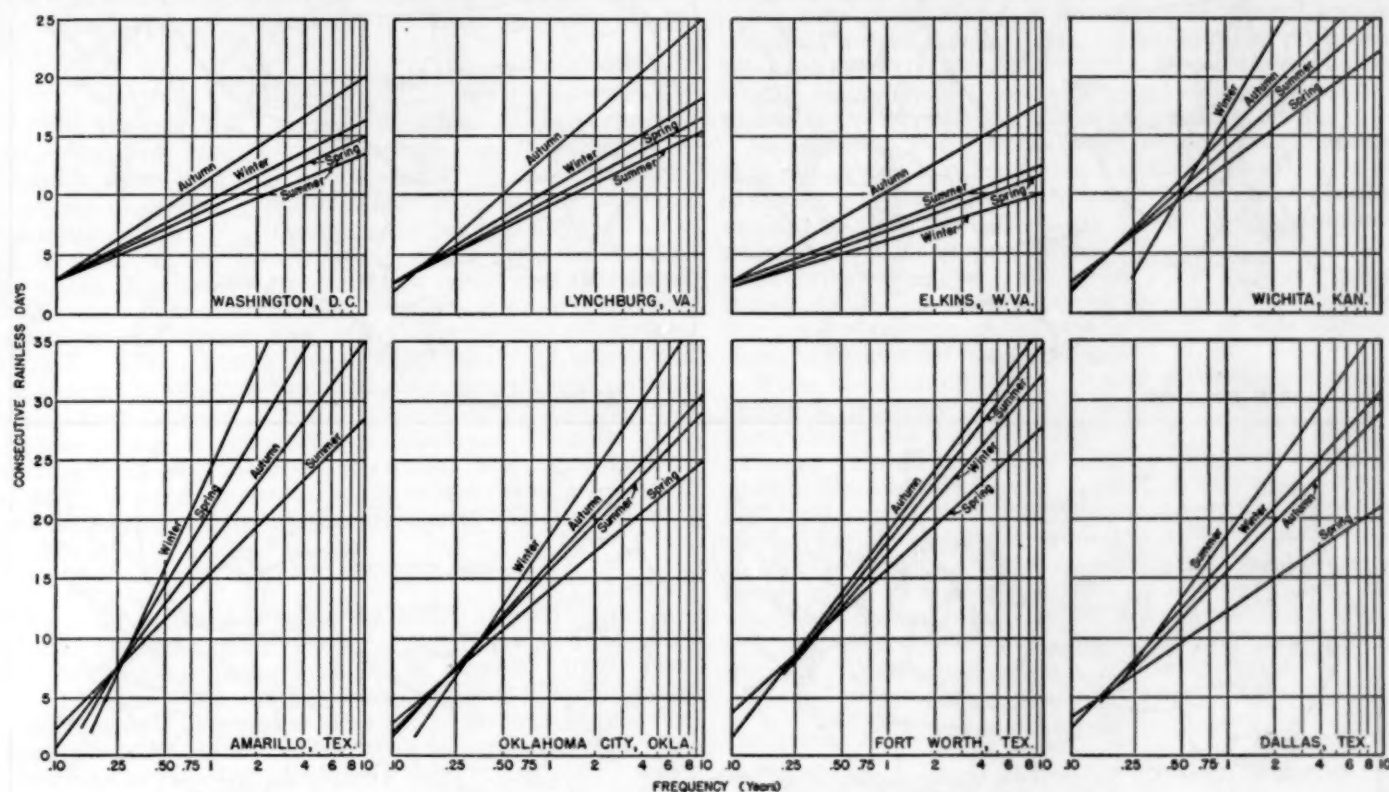


FIGURE 5.—Drought frequency curves by seasons for eight first-order Weather Bureau stations.

in the coastal area, as represented by Washington, autumn rains are more intense than those occurring in the spring. In the Prairie region, spring intensities for 15-minute periods are almost as high as summer intensities, while farther west at Amarillo and Dodge City intensities of spring rainfall are markedly less than those of summer but are about equal to those of autumn (fig. 4).

Rainfall duration and storm frequency both vary with the seasons. The warm-front storms characteristic of the winter season are of long duration. Summer showers of the thermal or frontal convective type<sup>16</sup> are short and more intense. Storm frequencies are highest during the summer and lowest during the winter, except at the three Prairie stations—Fort Worth, Dallas, Oklahoma City—

during the daytime. Evidence collected on many airplane flights indicates that the moisture, which produces nighttime precipitation in the Plains, comes from the upper levels of the atmosphere and suggests that it is released primarily through convection due to radiational cooling from either the tops of cumulus clouds or moist layers of air aloft.

A study of nighttime rainfall maxima in terms of the thermodynamic structure of the upper air shows that the dearth or abundance of summer convective rainfall in the Plains is associated with abnormalities in this thermodynamic structure.

A study of the frequency of rainless periods of varying length provides a basis for determining drought and consequent erosion hazard. Frequency curves showing the seasonal expectancies of rainless periods demonstrate that in addition to quantitative differences in the expectancies from station to station and area to area there are

<sup>13</sup> These stations were Lynchburg, Washington, and Elkins in the East; Dallas, Fort Worth, Oklahoma City, and Wichita in the Prairie area; and Amarillo and Dodge City on the High Plains.

<sup>14</sup> Blumensack, David I. Rainfall Characteristics as Related to Soil Erosion. U. S. D. A. Tech. Bull. (In press.)

<sup>15</sup> Thermal convection is that which arises through steepening of temperature lapse rates either by insolation heating at the surface or radiational cooling aloft. Frontal convection is caused by the release of the thermodynamic instability of the air by mechanical lifting along a frontal surface.

<sup>16</sup> Kincer, J. B. Daytime and Nighttime Precipitation and their Economic Significance. MONTHLY WEA. REV., 44:628-633, 1916.

also contrasts in the relative rank of the four seasons (fig. 5). The number of consecutive days without rain to be expected every year varies among the stations investigated from 33 at Amarillo, Tex., to 12 at Elkins, W. Va. The maximum number of consecutive rainless days occurs variously in summer, autumn, and winter at various stations, and for the one-year frequency ranges from 25 in winter at Amarillo to 10 in autumn at Elkins. The smallest seasonal maximum period of consecutive rainless days occurs in winter, spring, and summer at various

groups, but both indicate that summer drought expectancies are high, as contrasted with the lower expectancies for this season at Oklahoma City and Wichita.

By analyzing these data in connection with temperature and wind observations the drought hazard can be determined. Since only extremely high temperatures persisting several hours have in themselves a lethal effect on the type of crops raised in the Plains, it is necessary in most cases to consider temperature principally in relation to the rate of evaporation and the wilting point. Maxi-

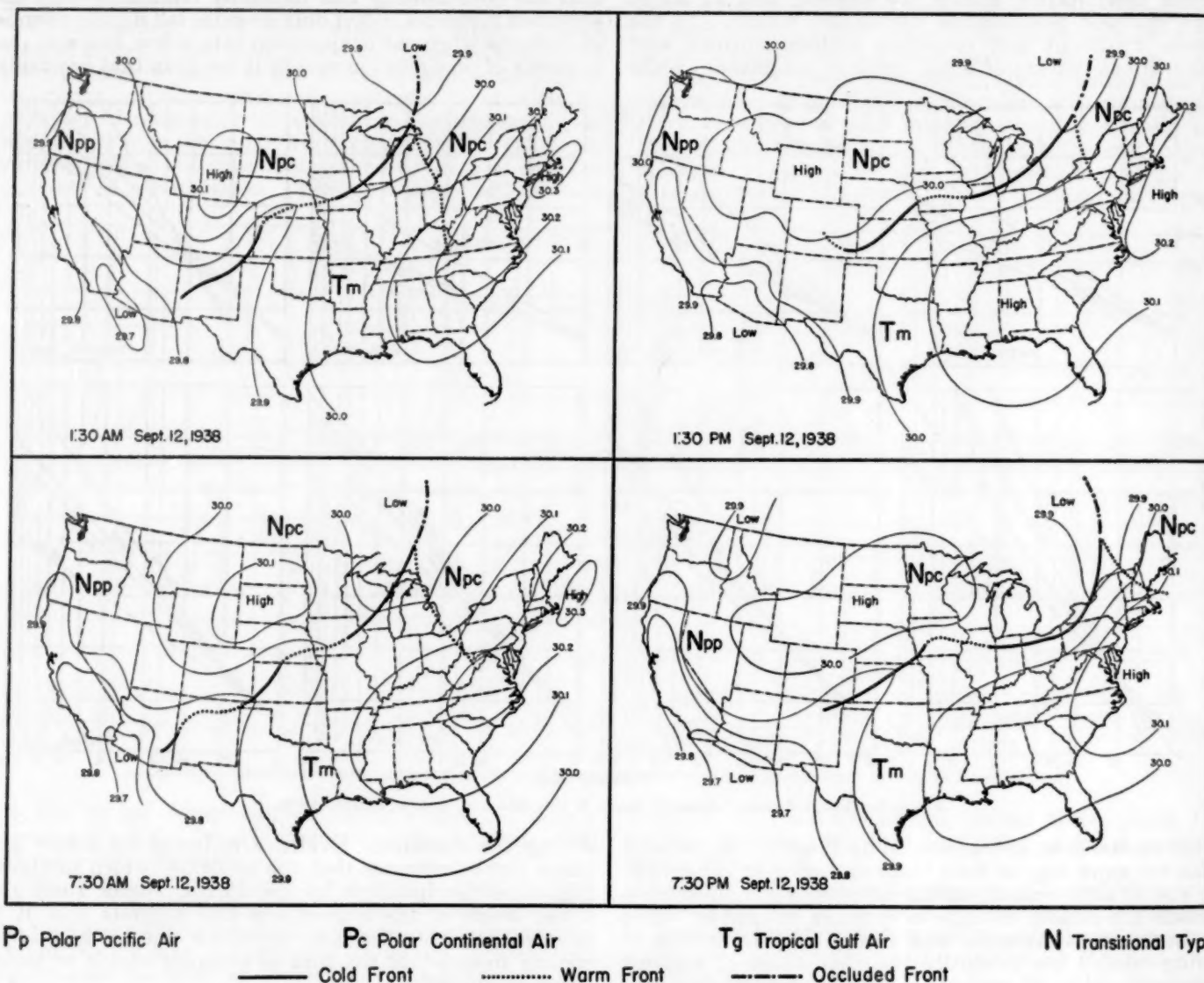


FIGURE 6.—Synoptic maps for September 12, 1938.

stations ranging from 16 in summer at Amarillo to 6 in winter at Elkins. In the East, seasonal expectancies rank in the same order at Washington and Lynchburg, summer rainless intervals being the shortest and those of autumn the longest; but Elkins, in the mountains to the west, experiences shorter rainless periods during winter and spring than during the summer. In the Prairie area, spring is characterized by the shortest rainless intervals; while on the High Plains to the west, as represented by Amarillo, the shortest rainless periods are experienced in summer, and spring has rainless intervals almost as long as those occurring during the winter. Minor differences are displayed between the Fort Worth and Dallas curve

and the Amarillo curve. Maximum temperatures are experienced in the Plains area of northern Texas, western Oklahoma, and western Kansas. These data will be of greater value when they are interpreted in the light of evaporation investigations now in progress.

Since drought may destroy the vegetation cover and since the alternation of wet and dry periods tends to break down the soil aggregates, frequency and length of rainless periods determine in part the availability of soil for wind transport. Therefore, the coincidence of maximum drought expectancy with periods of maximum wind velocity would create a particularly severe wind erosion hazard. Frequently, high wind velocities are of relatively

short duration and are associated with successive passages of cold or occluded fronts. The most spectacular "black" duststorms generally occur with these types of fronts but serious wind erosion can also occur during prolonged periods of moderate wind velocities. Wind erosion studies must be accompanied both by synoptic studies of the meteorological situations which yield "duststorm" conditions and by descriptive statistics on monthly and seasonal variations in wind velocity.

The various statistical studies discussed above will provide basic data for a series of climatic risk maps in terms of specific critical climatic factors. From these maps it will be possible to ascertain the climatic hazards which must be combated in any region if effective soil conservation practices and the necessary changes in farming techniques, crop calendars, and farm economy are to be adopted.

#### FIELD STUDIES OF CLIMATE

For climatic risk studies Weather Bureau records extending over a number of years are indispensable, since without them it would be impossible to determine frequencies of critical climatic values, such as precipitation intensity-frequency or frequency of rainless days. There is, however, in soil conservation, also a need for studies in which climatic observations are made and correlated with actual field observations of erosion processes and the resulting land forms and with observations of surface run-off. This requires the detailed study of individual rainstorms in relation to the types of run-off and erosion which they produce. Initial studies have indicated that various types of rainstorms produce characteristic patterns of run-off and forms of erosion, and have demonstrated the need for careful study of individual rainstorms and for the development of a system for rainstorm classification.

#### RAINSTORM MORPHOLOGY

In order to make possible the study of individual rainstorms, the Soil Conservation Service, in cooperation with the Weather Bureau, installed in October 1935, with W. P. A. funds, 200 weather stations, spaced approximately 3 miles apart, in an area of about 1,800 square miles in west-central Oklahoma. Over the entire area simultaneous observations of temperature, relative humidity, wind velocity, and wind direction were made each hour from 7 a. m. to 7 p. m., and during storms rainfall was recorded at 15-minute intervals.<sup>17</sup>

The results obtained were of sufficient value to justify the establishment in March 1937 of a similar microclimatic study in the Muskingum Valley in Ohio, where 500 weather stations, each including a self-recording rain gage in addition to the instruments supplied in Oklahoma, were spaced approximately 4 miles apart in the 8,000 square-mile watershed. More recently, recording anemometers and hygrothermographs were installed at half of the stations.

The records from both projects are used in the preparation of detailed climatic maps, the most significant of which are those of rainfall. The Oklahoma maps show the rainfall distribution for every 15-minute period and the accumulation of rainfall by 15-minute intervals for each storm. In Ohio, similar maps are prepared for half-hour intervals. Distribution of temperature, relative humidity, fog, dust, and wind velocity and direction are also mapped to help explain the rainstorms and permit their classification according to types. Supplementary

maps show the rainfall accumulation for each day on which precipitation occurred and the daily accumulations by months as well as for the entire year.

Rainfall records from 120 self-recording gages distributed over the entire upper Ohio and Susquehanna watersheds have been available since January 1, 1938, and maps of the rainfall of each hour are being made (figs. 6 to 11). Figures 6 to 11, inclusive, are presented to illustrate the type of material available for the investigations discussed in the following pages.

In each case the battery of raingages is regarded as a single instrument for obtaining simultaneous samples in different parts of rainstorms in sufficient number to determine their characteristics. Rainstorms are subject to the same kind of observation and classification as other phenomena, and through the analysis of a large number already observed, a beginning on a taxonomy of rainstorms has been made. It has been found that rainstorms have characteristics of size, shape, internal structure, distribution of intensity, and migration patterns.<sup>18</sup>

It is known from general meteorological considerations that rainstorms of other sections of the United States are of the same types as those in Oklahoma, Ohio, and Pennsylvania, and that the differences in rainfall characteristics which may exist in two regions are due to variations in storm type frequencies. Recognizing that each storm type is responsible for particular combinations of erosion forms, the great variation in erosion pattern in the different climatic regions becomes apparent.

When the characteristics of various rainstorm types are known it becomes possible to relate soil erosion to the particular storm which produced it; to note the effect of different rainfall intensities and durations in producing specific erosion results which can be determined in the field; and to contrast immediately adjacent areas where the rainfall sequences for the particular storm were not alike. In short, climatic data in a detailed quantitative form can be matched with corresponding quantitative field data based on observations made while erosion was actually in progress. The field thus becomes a laboratory in which the climatic factors of soil erosion become known.

#### SPACING OF RAINGAGES

The determination of the distribution, intensity, and duration of rainfall requires a sampling procedure since it is manifestly impossible to measure every drop. The accuracy of these determinations depends upon the relation of raingage spacing to size and structure of rainstorms. All storms possess basically similar structural characteristics, each having one or more nuclei of high rainfall intensity and large total precipitation amounts which diminish as one approaches the periphery. General storms covering several hundred thousand square miles require no more gages to obtain an adequate sample than do local showers of only a few hundred square miles in extent, since with an increase in storm size the precipitation variability per unit area decreases. For sampling general storms the existing network of first-order and cooperative Weather Bureau stations is adequate as to spacing, but recording gages are needed at more of these stations. For small summer thunderstorms the network is totally inadequate both with respect to spacing and type or record obtained.

The question of raingage spacing depends first of all on the specific purpose for which the observations are to be

<sup>17</sup> Thornthwaite, C. Warren. The Life History of Rainstorms. Progress Report from the Oklahoma Climatic Research Center. Geogr. Rev., Vol. XXVII, No. 1, pp. 92-111, January 1937.

<sup>18</sup> Thornthwaite, C. Warren. Microclimatic Studies in Oklahoma and Ohio. Science, Vol. 86, No. 2222, pp. 100-101, July 30, 1937.

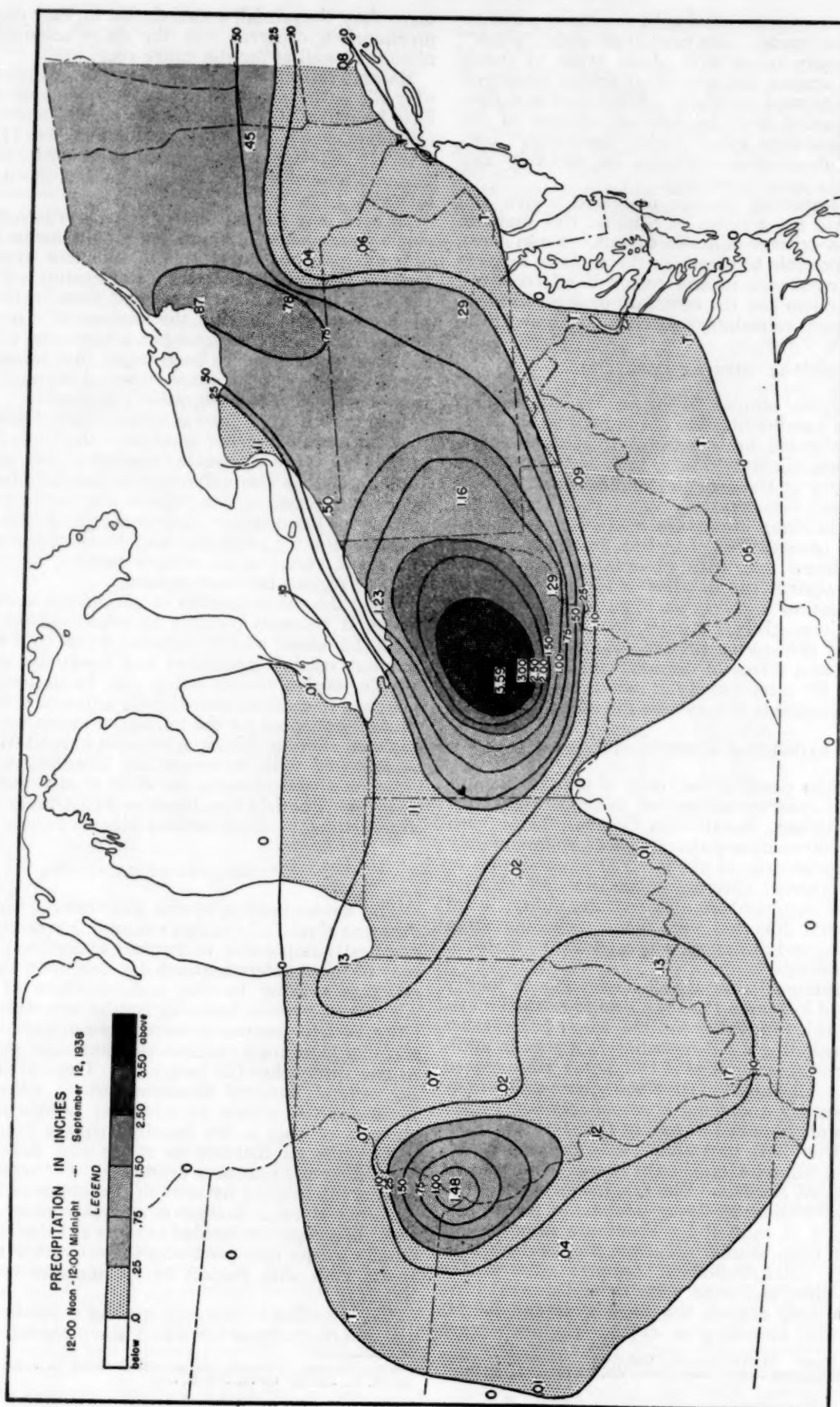


FIGURE 7.—Precipitation in inches over northeastern United States for the 12-hour period, noon to midnight, September 12, 1938. Records are from the first-order stations of the Weather Bureau.

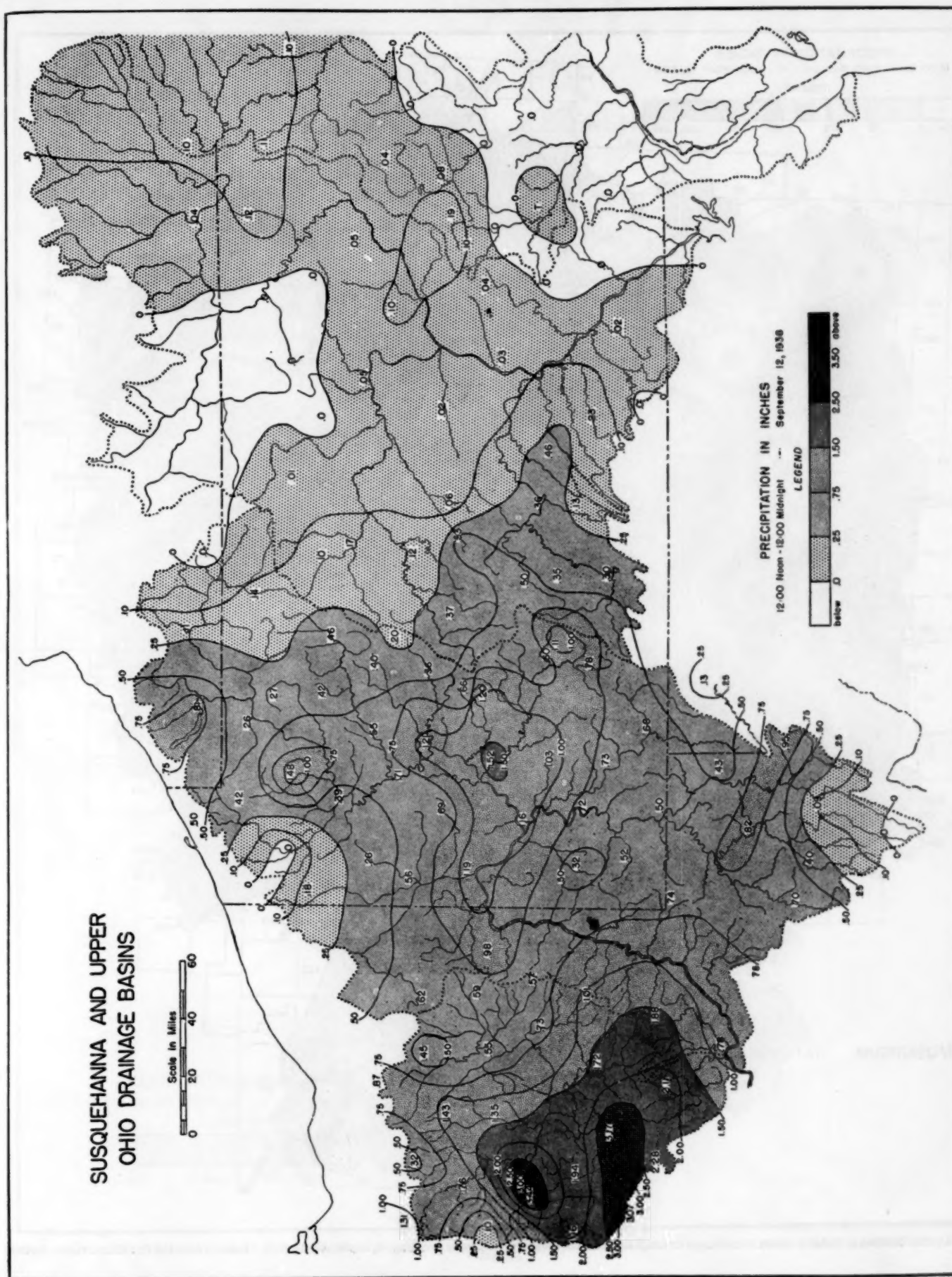


FIGURE 2.—Precipitation in inches over the upper Ohio and Susquehanna drainage basins for the 12-hour period, noon to midnight, September 12, 1928. Records supplied by the Soil Conservation Service, the Weather Bureau, the Forest Service, the Geological Survey, the Army Engineers, the Commonwealth of Pennsylvania, and private interests.

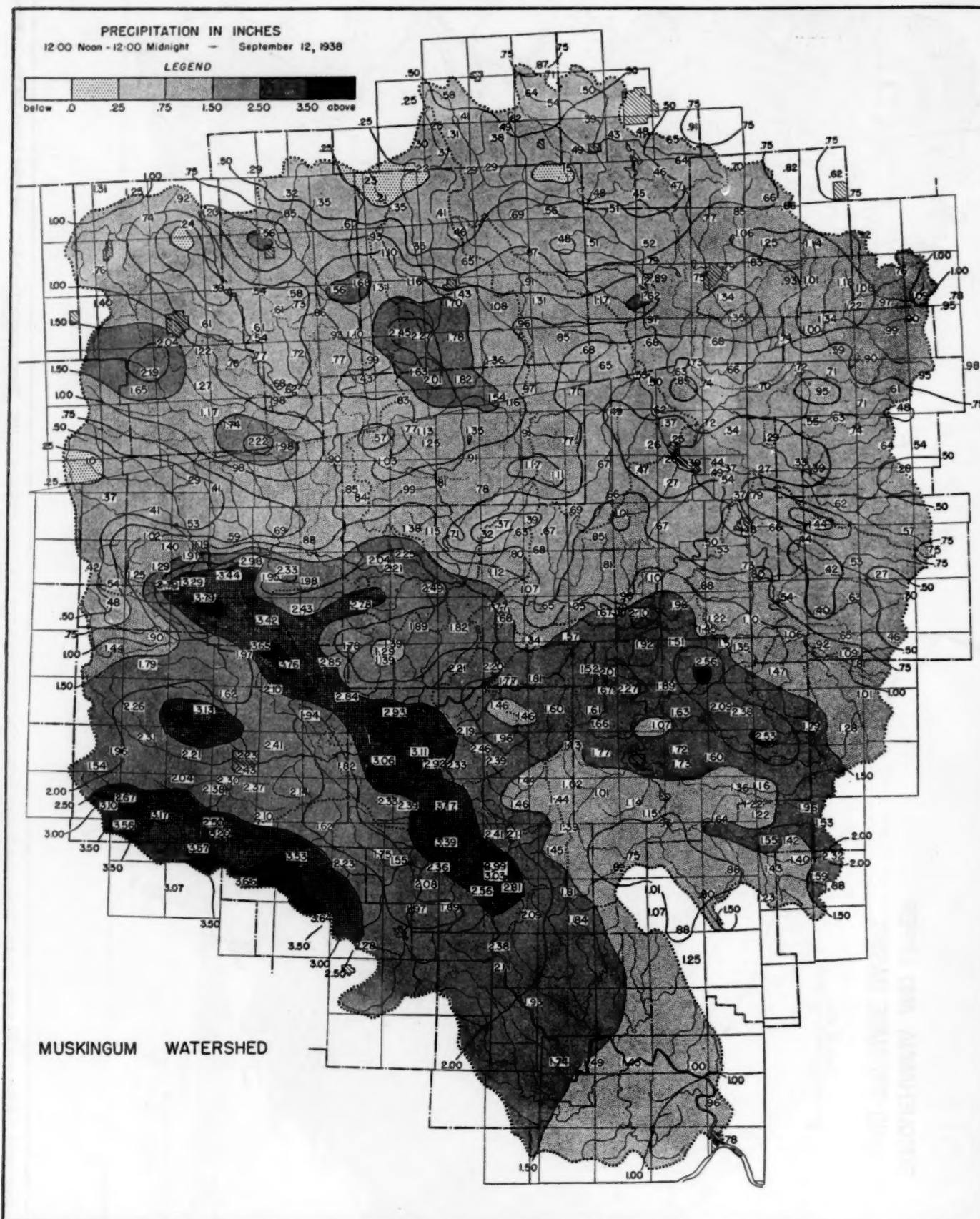


FIGURE 2.—Precipitation in inches over the Muskingum drainage basin for the 12-hour period, noon to midnight, September 12, 1938. Records from the Soil Conservation Service.

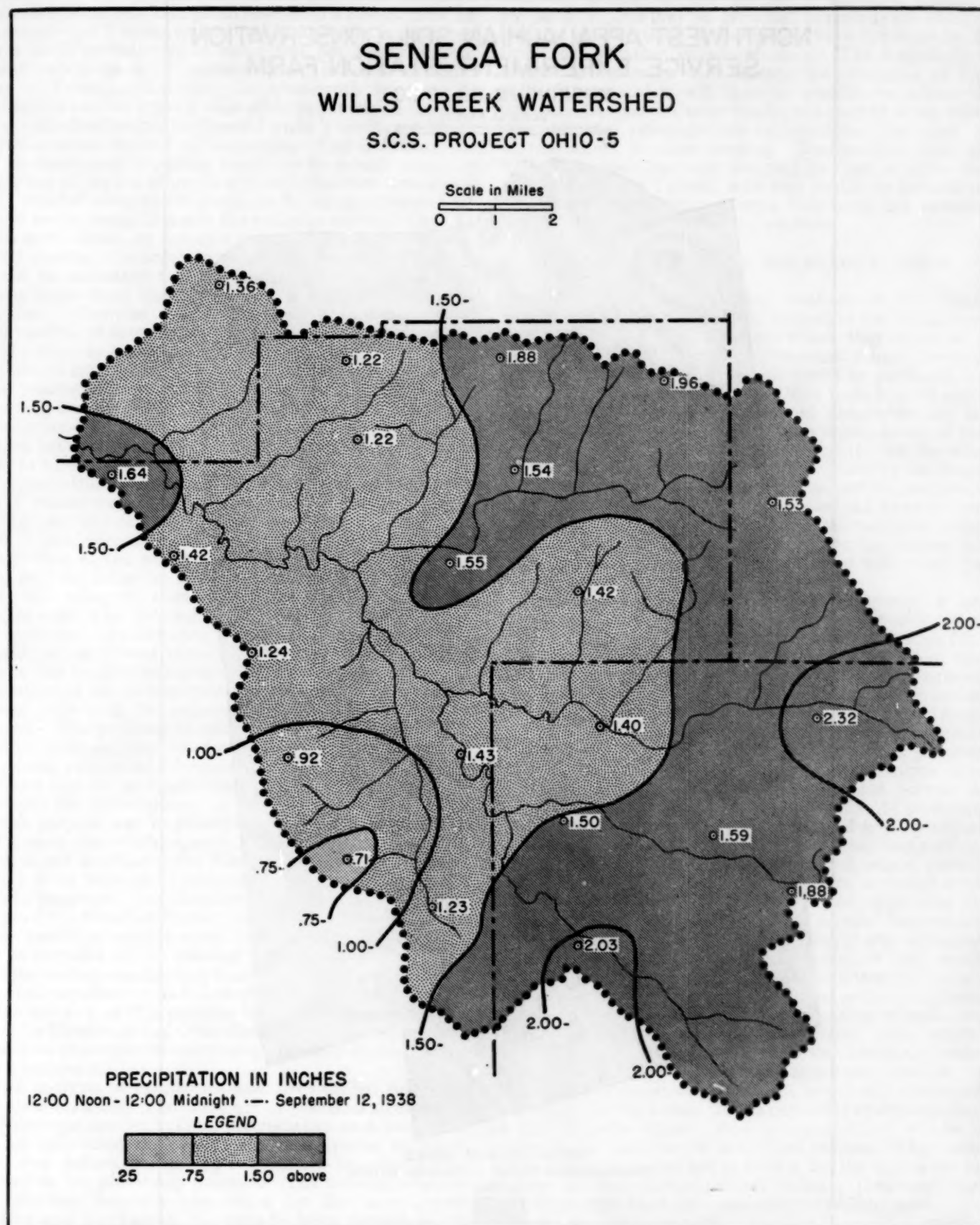


FIGURE 10.—Precipitation in inches over the Senecaville, Ohio, project area for the 12-hour period, noon to midnight, September 12, 1938. Records from the Soil Conservation Service.

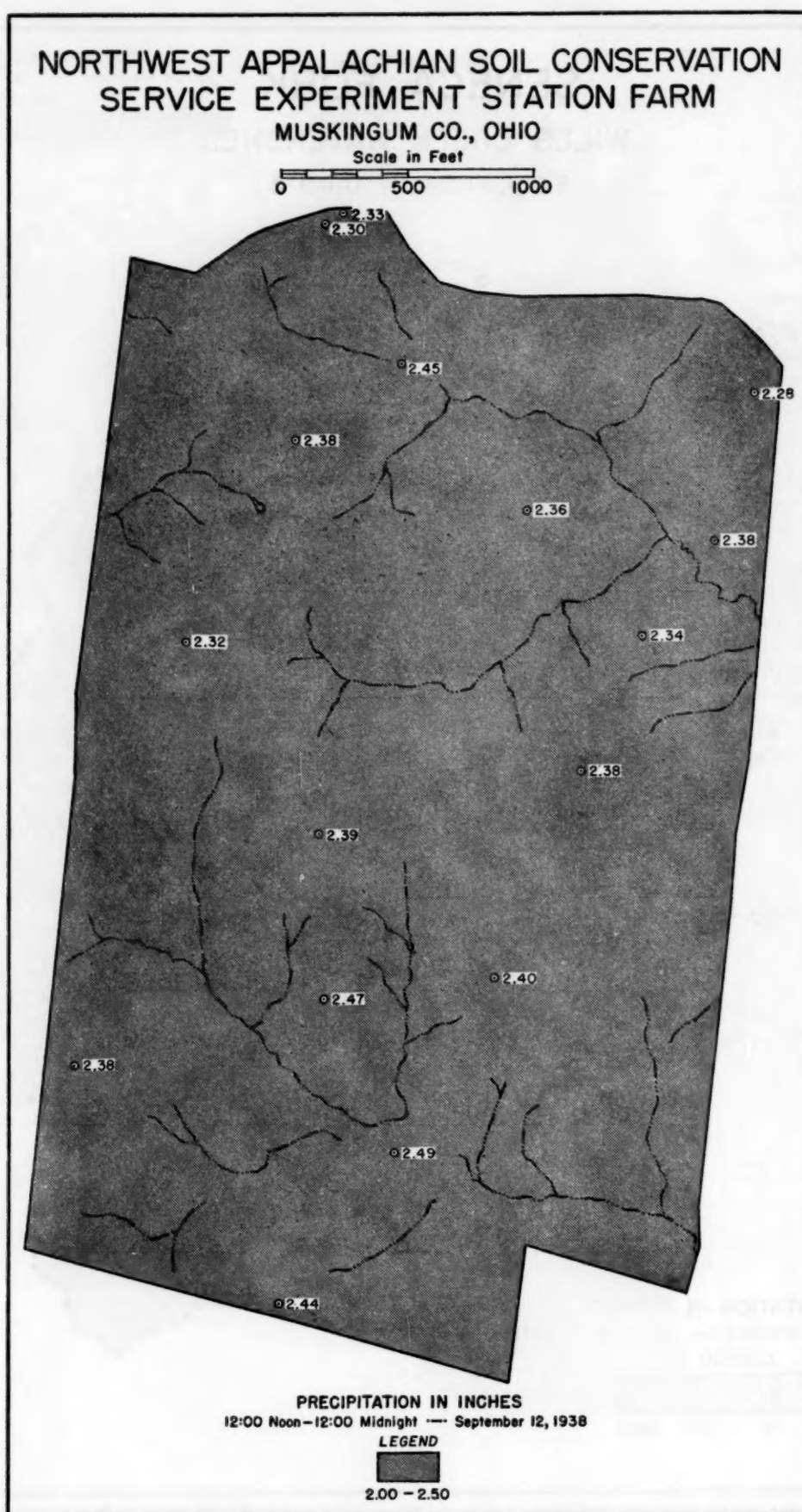


FIGURE 11.—Precipitation in inches over the Soil and Water Conservation Experiment Station at Zanesville, Ohio, for the 12-hour period, noon to midnight, September 12, 1938. Records from the Soil Conservation Service.

made. For flood forecasting, water stages in excess of definite critical height in given reaches of a stream must be anticipated. A given water level in a stream is produced by a definite discharge in cubic feet per second which, under conditions of 100 percent run-off, is due to a definite rate of rainfall. Knowing the area-depth relations of various rainstorm types it is possible to determine the area of the smallest storm that would yield a discharge which would produce the critical flood stage. The determination of the spacing of raingages necessary to permit adequate sampling of such a storm is a straightforward procedure.

If rainfall observations are made for the purpose of storm sewer design in a city the raingage network must be such as to obtain an accurate measure of the structure of small storms. In order to obtain representative data it would be necessary to have the network cover an area much larger than that involved in the particular design problem; otherwise too few storms would be sampled. The method of determining the appropriate spacing would be the same as that already described.

Rainfall figures used by agronomists in studying climate-crop relationships must be sufficiently detailed so that the sampling error is not large enough to affect the significance of their conclusions and will depend on the type of investigation being conducted. In no case would a single raingage in a county be sufficient because of the small size and random distribution of summer convectional storms, which are of paramount importance to growing crops.

The problem of crop forecasting is complementary to that of flood forecasting, the former being concerned with the portion of the precipitation which is retained on the land and the latter with that which runs off. Nevertheless, the raingage spacing appropriate for agronomic studies cannot be determined in the same manner as that for hydrologic studies since climate-crop studies involve a consideration of local variations in distribution of rainfall due to the random occurrence of storms as well as a consideration of storm sequence while flood studies are concerned only with the volume of water delivered into a stream. The problem of raingage spacing for agronomic studies, however, requires for its solution a knowledge of rainstorm pattern and frequency.

There can be no single ideal raingage spacing equally desirable for all purposes. A network perfectly adapted for one purpose may be grossly inadequate for another and at the same time extravagantly excessive for a third. It is, thus, unfair to criticize the Weather Bureau for the distribution of its network of raingages, since it is adequate for certain purposes. On the other hand it would be unfortunate if the Weather Bureau were to fail to recognize that other problems require more detailed rainfall data than can be supplied by the existing network.

Since station-spacing as a sampling problem is of critical practical significance in soil erosion studies, work leading to the solution of this problem is now in progress. Data from the Oklahoma and Ohio climatic research centers and principles of rainstorm morphology already developed are being employed.

The analysis of rainstorms and the detailed precipitation data on which it is based are of practical significance in hydrologic studies. Total precipitation on a watershed can be calculated for any storm with greater accuracy than ever before, permitting refinements in rainfall-run-off studies not previously possible. The determination of precipitation intensity-frequencies by the station-year method and by Yarnell has already been discussed. It was pointed out that the chief limitation of Yarnell's material was due to the wide spacing of raingages. For such areas as the Muskingum Watershed, where micro-

climatic studies are in progress, Yarnell's intensity-frequency figures may be corrected to include the observations of small intense storms which were not recorded by first-order Weather Bureau stations. The magnitude of correction necessary will indicate the reliability of Yarnell's figures and it will then be possible to adjust the intensity frequencies accordingly, not only in areas where closely-spaced raingages are in operation but also, by extrapolation, in other regions. Results thus obtained, while not absolutely accurate, will be more reliable than those derived by Yarnell, who was unable to include the large number of intense storms that were not recorded at first-order Weather Bureau stations.

#### DETERMINATION OF THE MAXIMUM STORM

In addition to the statistical methods of determining frequencies of intense rains a technique for transposing maximum storms from the area where they occurred to other areas where they might reasonably have occurred and where a maximum of run-off would be produced, has been in use for several years.<sup>19</sup> The technique of storm transposition is a useful means of supplementing the statistical methods and increases the applicability of precipitation intensity-frequency data, but it, like the other techniques, is subject to limitations imposed by the length of records for the stations used. These techniques involve the analysis of past rainfall experience and have no way of determining the probability that the maximum storm already experienced can be surpassed in the future, nor can they indicate by what amount and with what frequency it might be surpassed.

Studies of individual storms have suggested a new approach to the problem of calculating possible storm maxima. By studying the detailed synoptic maps for a variety of storms which yielded excessive amounts of rainfall it would be possible to determine the values of meteorological elements involved in producing precipitation. Such factors as the slope of frontal surfaces, rate of ascension of moist tropical air over polar air, and the thermodynamic structure of air masses with respect to potential energy available for convection and maximum total precipitable moisture could all be ascertained. From the values derived, the factors most favorable to prolonged and intense precipitation could be selected and, by adjusting their values upward within reasonable meteorologic limits, possible synoptic situations which would provide higher rainfall than had previously been recorded could be anticipated. In some meteorological situations the possibility of altering the value of certain factors that participate in the production of high precipitation amounts is precluded, but in every synoptic situation there would be some elements that could logically be altered to increase the computed maximum rainfall. The method employed would be based on real data representing specific conditions already experienced but would yield rainfall figures which although in excess of the maxima recorded to date, would still be below the maximum possible. A genetic classification of rainstorms, now being developed, will bring out the salient points regarding storm evolution in any climatic region. Such a classification will be of value in the analysis of individual storms. That some such technique is needed is shown by the numerous instances of dam failure, which indicate that maximum storm amounts have been seriously underestimated.

<sup>19</sup> The method of storm transposition was described and illustrated by Adolph F. Meyer in a text, "Elements of Hydrology" first published in 1917. Merrill Bernard has introduced certain refinements through the use of the unit hydrograph (U. S. Geological Survey, Water-Supply Paper 772, pp. 218-244) and Gail Hathaway has followed the practice of studying the meteorological background of storms transposed.

## FIELD MOISTURE DEFICIENCY AS A CLIMATIC FACTOR

Studies of climatic risk and of climate-crop relationships where precipitation is the climatic factor involved, have yielded results less precise than are needed. One important reason for the failure of these studies is that it was attempted to relate the total precipitation to the crop growth or yield data. Since losses through run-off and evaporation are considerable but variable it is obvious that correlations should be made with that portion of the precipitation remaining in the soil and available for plant use, rather than with the total. This residual precipitation is field moisture and should be obtainable as a difference between precipitation and run-off. Attempts to derive an equivalent index or coefficient, evaluating precipitation in terms of evaporation, temperature, or other factors have been made by many investigators.<sup>20</sup>

Hydrologists have made use of similar run-off coefficients in which the ratio of run-off to precipitation is determined. Such coefficients are unsatisfactory because they ignore the fact that precipitation is a definite physical quantity and that those portions which run off and which do not are likewise definite physical quantities. In order to be satisfactory a precipitation-effectiveness index would be expressed in the same units as the precipitation and would include only that portion of the precipitation which is available for plant growth.

Researches leading to the development of a climatic index of soil-moisture conditions have required a detailed study of rainfall-run-off relationships. For this purpose, data collected in the Muskingum Valley in Ohio have been drawn upon. There, run-off has been determined for several years at many stream gaging stations on the main stream and its tributaries, and with the establishment of a dense network of raingages and other meteorological instruments it became possible to examine the rainfall-run-off problem in great detail. For practical reasons the study was limited to the Upper Licking watershed, approximately 800 square miles in area.

Familiar are the hydrologic generalizations that run-off equals rainfall minus losses through evaporation and transpiration and that run-off consists of surface run-off plus base flow or ground water run-off. It has been possible with a fair degree of accuracy to determine surface run-off and base flow as well as precipitation on the Upper Licking. The portion of the precipitation which does not run off remains in the soil to replace the soil moisture which has previously been lost by evaporation and transpiration. The amount of this replacement, being the difference between the two known values, is easily determined. The rate at which the loss is built up and its areal distribution cannot be determined in this straightforward manner. Progress in the instrumental determination of evapo-transpiration will be discussed in a later section. Recognizing the practical impossibility of obtaining observational measures of evapo-transpiration losses on any widespread scale for some time, a plan to determine them empirically was inaugurated.

A number of basic postulates were necessary: (1) Water in the soil consists of soil moisture and ground water; (2) soil moisture is the capillary moisture or field moisture which the soil can hold against gravity plus hygroscopic

water; hygroscopic water is an inseparable part of the soil complex, while the remaining water can be lost only through evaporation and transpiration; (3) ground water is a surplus which the soil cannot hold against gravity and which produces base flow or ground water run-off in streams; (4) soils have inherent field moisture capacities and have inherent rates at which field moisture and ground water can be increased; (5) surface run-off occurs only after the inherent moisture capacities have been reached or when the rate of infiltration is exceeded by the rate of precipitation; (6) field moisture deficiencies at the time of a rainstorm largely determine the characteristics of run-off resulting from the storm.

At the present stage of inquiry the rate of moisture loss from the soil through evaporation and transpiration is assumed to be a direct function of the saturation deficit and the wind velocity. While this assumption is not strictly warranted because of the other parameters involved in the evaporation relationship, it is being used pending the completion of evaporation studies, now in progress, which will provide new information regarding the evaporation process. Furthermore, there is a decrease in the rate of evaporation from the soil during rainless periods, as the moisture surface moves downward in the profile. New moisture cannot be supplied from below because the rate of evaporation far exceeds that of capillary movement. There is a similar decrease in transpiration since the number of rootlets supplied with ample water constantly decreases during rainless periods. For these reasons the general assumption involving wind and saturation deficit has been modified to allow for a deceleration in rate of moisture loss.

Using this method, reasonably accurate continuous values of surface run-off and base flow have been calculated from meteorological observations alone. These values provide the only possible present check to the accuracy of the empirically determined field-moisture deficiencies. Further refinements are, however, necessary and will involve the use of infiltration rates for specific soil types and a consideration of the influence of farming operations.

The recency of plowing, the depth of the furrows, and the nature and maturity of the crop will affect the amount of surface storage of water, the rate of overland flow, and the rates of evaporation and transpiration. Since early spring of 1938 the farming operations and the condition of land and crops over the entire Upper Licking watershed have been under constant observation by field men who cover established routes once each week. From their reports on the condition of the land at the time of each rain it is hoped that a definitive answer may be given to the question of the influence of land-use practices on run-off and floods on large watersheds.

Because of the small size of many rainstorms in summer especially and their random distribution in an area, resulting in great areal variations in rainfall even in a region of limited size, there is frequently developed considerable local variation in field-moisture deficiency even where potential evaporation and transpiration losses are uniform. Where climate-crop studies are based on effective precipitation rather than total precipitation it is especially necessary that a fine network of rain gages be available.

It has been pointed out that because of the infinite variety of possible combinations and sequences of individual climatic elements the climate of each crop year is unique and could never be repeated exactly (see footnote 4). It is equally true not only that the field moisture deficiency regime of a place will not be duplicated in

<sup>20</sup> Discussions of a number of such attempts will be found in Thornthwaite's *Climates of North America According to a New Classification* (footnote 3, p. 634). The following recent summary articles should be consulted in this connection:  
Philipppis, A. de. *Classificazioni ed indici del clima in rapporto alle vegetazione forestale italiana*. Nuovo Glor. Bot. Ital. N. Ser., vol. 44, No. 1, pp. 1-169, 1937.  
Rubner, K. *Die forstlich-klimatische Einteilung Europas*. Zeitschr. für Weltforstwirtschaft, Band 5, heft 6, pp. 422-434, March 1938.  
Moreau, R. E. *Climatic Classification from the Standpoint of East African Biology*. Jour. Ecol., vol. 26, No. 2, pp. 467-496, August 1938.

another year but also that it will not be duplicated in another place.

Since the rainfall sequences at stations within a few miles of each other are frequently quite different, what amounts to several years of rainfall experience can be obtained in a single year. Hence, where the climate-crop studies involve field experimentation, as is frequently the case, simultaneous identical experiments in a number of places would yield in a single year the equivalent of several years results from ordinary climatic records. Recognizing this fact, the Ohio Agricultural Experiment Station and the Division of Crop and Livestock Estimates are planning active cooperation with the Soil Conservation Service in Ohio, where the wealth of detailed climatic data are being obtained.

A further implication of local variations in field-moisture deficiency should be mentioned briefly. In run-off and flood forecasting studies where run-off coefficients are used, great difficulty is encountered in determining in advance just what percentage of the precipitation will run off, a necessary factor where run-off is predicted from rainfall values alone. The great variation in the run-off coefficient is due largely to variations in field moisture deficiency since generally little run-off will occur, except in intense rains, from an area until the deficiency is removed.

In order to determine a run-off coefficient to be used in forecasting run-off using rainfall data the so-called index area method has been suggested. The method requires a small watershed within the large one for which forecasts are to be made and which is supposed to be representative of the large one. On the small index watershed, detailed rainfall and run-off data make prompt determination of a run-off coefficient possible. Assuming, then, that the run-off coefficient of the index watershed bears some consistent relation to the coefficient of the large watershed, it becomes possible to obtain the required run-off coefficient.

As has been pointed out previously, the effect of small local storms is to develop considerable local variation in field-moisture deficiency. Since the local storms occur in random fashion, the index area will frequently be missed by a series of small storms which occur elsewhere over the large watershed or the index area may be visited by storms not received elsewhere. In the first instance the field-moisture deficiency of the index area will be greater than that elsewhere in the watershed, whereas in the second case the deficiency will be less. In either case a run-off coefficient derived from the index area and applied to the watershed will yield erroneous run-off determination.

Almost invariably floods on large watersheds are due to general rains, which remove the field-moisture deficiency from a considerable area. Insofar as the field-moisture deficiency of the watershed varies from that of the index area at the time of a flood-producing rain the flood forecasts using the index area method will be in error.

If it becomes possible to determine field-moisture deficiency from meteorological data alone each station on a watershed from which rainfall records are obtained for flood forecasting should serve as an index station. When a general rain occurs the portion required to restore soil moisture in the neighborhood of each station could be deducted and the remainder used in the run-off computations. In this manner flood forecasts should be improved.

#### STUDIES ON EVAPORATION

In the consideration of the relationships between rainfall, run-off, and soil-moisture deficiency it has been seen

that evaporation is a critical quantity. In climatic classification the need is felt for refinement based on further knowledge of actual evaporation, and in investigation of climatic risks, such as drought, evaporation is a highly significant element. However, among all the climatic factors of agricultural significance, the measurement of evaporation has probably offered the most difficulty and for that reason is least well-known. Work has, therefore, been initiated with a view towards obtaining more specific information concerning evaporation.

Of the total precipitation that falls on continental areas, part is returned to the oceans as run-off and underground water flow and the remainder is eventually returned to the atmosphere by evaporation from the surface of the ground and from water surfaces such as rivers and lakes, and by transpiration from plants. A recent publication<sup>21</sup> based on aerological data and using modern meteorological analysis, has shown that the amount of reprecipitation over land areas of land-evaporated moisture is so small in comparison with the precipitation derived from oceanic source regions that it is of minor significance in any general consideration of the hydrologic cycle. Precipitation is derived principally from air masses whose source regions are the oceans and evaporation takes place mainly into dry continental air masses.

The role of evaporation in the hydrologic cycle is significant, therefore, not because of the amount of reprecipitation which may occur but because evaporation is the mechanism whereby soil moisture and stored water are depleted. Hydrologists and agronomists are both vitally concerned with the rate at which this loss occurs. It is therefore the task of the climatologist to determine actual evaporation rates under different atmospheric conditions and under different conditions of surface cover and land use. Such information would make possible the determination of the moisture regime of climatic regions and subregions or of areas of even smaller size.

#### THE DETERMINATION OF ACTUAL EVAPORATION

Most of the current methods of measuring evaporation employing some type of pan or atmometer have proved unsatisfactory. These methods have led to the development of empirical evaporation formulae whose parameters include such surface observations as temperature, salinity, relative humidity, barometric pressure, and wind velocity.

While pan and atmometer measurement permit a general qualitative estimate of the evaporation-opportunity, they are useless in determining actual transpiration and water losses from extensive land areas. As plant physiologists have shown, the amount of transpiration for any plant type is partly a function of the leaf area of the plant. This introduces a factor which varies seasonally and is associated with the growth curve of the plant. Transpiration also varies from one plant species to another, depending upon the water requirements of the plant, the osmotic pressure in the leaves, and the number, nature, and size of the stomata. None of these factors is reflected by pan or atmometer measurements of evaporation.

Furthermore, such evaporation data do not measure evaporation from the soil. When the surface soil is moist the evaporation, in the case of finer soils, exceeds pan measurements because the soil presents a greater

<sup>21</sup> Holzman, Benjamin. Sources of Moisture for Precipitation in the United States. U. S. D. A. Tech. Bull. No. 589, October 1937.

evaporating surface associated with minute irregularities in the soil surface and because surface soil temperatures are usually higher than evaporimeter surface temperatures during that part of the day when most of the evaporation occurs. When, however, the surface soil is dry or partially dry, less evaporation occurs from the soil than from a pan. Even though the subsoil is moist, capillary action cannot supply the surface with water at a rate at all comparable to the evaporation from a free body of water. Hence water molecules can escape to the outer air only through a very slow diffusion process which takes place from the lower soil levels and through the soil air.

A method is needed which will measure the rate at which moisture enters the lower air, regardless of the type of surface involved. This involves a consideration not only of surface parameters but also of specific humidity gradients and conditions of turbulence in the atmosphere. In general, it may be said that when atmospheric turbulence is at a minimum, evaporation will also be at a minimum. When there is no turbulent motion, the upward transport of water vapor can take place only by diffusion. This process is analogous to the transfer of heat by conduction. In the atmosphere both of these processes are negligible when compared to the magnitude of heat or moisture transfer by turbulent or convective phenomena.

Although the theoretical treatment of problems of turbulence is highly complex mathematically, significant progress has nevertheless been made in this field especially through the efforts of the Göttingen School of Aerodynamicists—Prandtl,<sup>22</sup> von Karman,<sup>23</sup> Tollmien,<sup>24</sup> and others. Many of their ideas have been extended and applied to the atmosphere and ocean by Rossby<sup>25</sup> and Sverdrup.<sup>26</sup> As an outgrowth of Rossby's research an atmospheric turbulence, a method for determining evaporation is being tested at the Muskingum Climatic Research Center and at the Arlington Experimental Farm. Preliminary data already obtained indicate the complete feasibility of the technique.

The method depends upon a measurement of the specific humidity gradient and a measure of the intensity of the turbulent mixing conditions in the lower levels of the atmosphere. Turbulence tends to establish an adiabatic distribution of properties of the air and thus a constancy in the moisture concentration. In other words, the specific humidity throughout the turbulent layer would

be constant provided no moisture were added or subtracted from the layer. Thus, in the turbulent layer immediately adjacent to the ground, a moisture gradient directed upward, that is, a lower specific humidity aloft than at the surface, indicates an addition of moisture from below by evaporation and its upward transport. On the other hand, if the gradient is directed downward, moisture is being abstracted at the ground surface by dew or frost, and downward transport of moisture results.

Experiments being conducted at present are limited to plots in which the ground surface is relatively smooth and homogeneous. The turbulent mixing condition is determined from simultaneous measurements of wind velocity at various elevations above the ground. Hygrothermographs are stationed adjacent to the ground surface and at different elevations so that the specific humidity gradient can be determined. A relatively simple formula gives evaporation in inches per hour where specific humidity and wind velocity at two different levels and the height of the two observation points above the ground are known.

If this method of determining the amount of moisture returned to the atmosphere proves to be practical it will have the obvious advantage of measuring the actual rate of transfer of water vapor into the atmosphere. The isolated local factors that influence evaporation would be combined and a true value for the moisture losses to the air obtained. These true values are the ones so urgently needed in the refinement of many agricultural and hydrologic problems.

#### SUMMARY

Climatic work carried on as an integral part of the research program of the Soil Conservation Service has clearly demonstrated the need for a variety of specialized climatic investigations into soil erosion problems. Many of these climatic problems have already been undertaken, several have been completed, but there are still numerous questions which, while clearly recognized, have yet to be subjected to study. General climatic considerations are useful in defining "erosion regions" and in treating the element of climatic risk. Analyses of precipitation records in terms of storm duration, intensity, and storm area have been undertaken and are being directly related to field phenomena. Drought is being considered as a type of climatic risk particularly significant in the Great Plains and the semiarid West. Temperature in its bearing on climatic risk and weathering processes is also being scrutinized. Likewise, a consideration of the flood problem in its bearing on erosion hazards requires studies of excessive precipitation, actual evaporation from various types of land surfaces, and soil-moisture deficiency. Thus, in a wide variety of ways, a number of climatic studies are being carried out. That climate is an inseparable major theme in the soil erosion complex is clear. The objective is to orient the climatic work in such a way that results of maximum practical value will be obtained.

<sup>22</sup> Prandtl, L. *The Mechanics of Viscous Fluids. Aerodynamic Theory.* Wm. Frederick Durand (Editor-in-chief), vol. III, Div. G, pp. 34-207, Berlin, Julius Springer, 1935.

<sup>23</sup> von Karman, Th. *Mechanische Ähnlichkeit und Turbulenz.* Nachrichten von Gesellschaft der Wissenschaften zu Göttingen. Math. Phys. Klasse, Heft 1, pp. 58-76, 1930. Idem: *Turbulence.* Jour. Royal Aeronautical Soc., vol. XLI, No. 324, pp. 1109-1143, illus. December 1937.

<sup>24</sup> Tollmien, Walter. *Berechnung turbulenter Ausbreitungsvorgänge.* Zeitschr. für angewandte Mathematik und Mechanik, band 8, heft 1, pp. 458-478, 1926.

<sup>25</sup> Rossby, C. G., and R. B. Montgomery. *The layer of frictional influence in Wind and Ocean Currents.* Mass. Inst. of Tech. Papers in Phys. Oceanography and Meteorology, vol. III, No. 3, Cambridge, Mass., 1935.

<sup>26</sup> Sverdrup, C. G. *A Generalization of the Theory of the Mixing Length with Applications to Atmospheric and Oceanic Turbulence.* Mass. Inst. of Tech. Meteorol. papers, vol. I, No. 4, pp. 1-36, 1932.

<sup>27</sup> Sverdrup, H. U. *Das maritime Verdunstungsproblem.* Annalen der Hydrographie und Maritimen Meteorologie, band 64, heft 2, pp. 41-47, 1936.

## SOUNDING-BALLOON OBSERVATIONS MADE AT OMAHA, NEBR., DURING THE INTERNATIONAL MONTHS JUNE 1935, NOVEMBER 1936, AND AUGUST 1937, AND WINDS OBSERVED DURING JULY 1938

By J. C. BALLARD

[Weather Bureau, Washington, D. C., September 1938]

The sounding-balloon observations made at Omaha, Nebr., by the Weather Bureau during the international months June 1935, November 1936, and August 1937, were a part of the worldwide system of observations made in cooperation with the International Aerological Commission. They were similar in character and schedule to sounding-balloon observations made during previous international months. That is, one observation was made each day about an hour and a half before sunset and, in addition, on 3 days during June 1935, 3 during November 1936, and 6 days during August 1937 an observation was made daily just after sunrise.

All of the sounding-balloon data for various standard and the significant levels have been furnished to the International Aerological Commission along with airplane, pilot-balloon, and cloud observation data obtained during the 3- or 6-day international periods each month; the detailed data will be published by that Commission.

However, for the convenience of those who might be interested in knowing just what data are available, tables 1, 2, and 3 have been prepared and are presented here. A few statistical data and a discussion of them are also given.

Fergusson sounding-balloon meteorographs were used in all the flights and only one balloon was used in each ascension. The arrangement of equipment was in the order: balloon, parachute, 75 to 100 feet of cord, and meteorograph. The balloons used in June 1935 were the same type as those used in the previous several series of observations. Those used in November 1936 and August 1937 were a newer type recently developed and, as the heights attained indicate, were quite satisfactory. The balloons averaged about 350 g in weight, and about 40 inches in diameter, uninflated. The parachutes were made with pieces of silk or rayon about a yard square for all equipment weighing 300 to 400 g. Parachutes about 54 inches square were used with heavier equipment.

In June 1935 and November 1936 the balloons were filled to give them an average free lift, after all equipment was attached, of about 650 g. Such a filling gave the balloons a diameter of around 5 feet. During November 1936 pieces of additional experimental equipment were attached at various times so that the weight of equipment carried by the balloon was usually about 300 g (the weight of the apparatus using a Fergusson instrument only), 950 g, or 1,700 g. The average height at bursting of the balloons carrying 300 g of equipment was roughly 23 km, of the 9 balloons carrying 950 g about 21 km, and of the 4 carrying 1,700 g also about 21 km. Three of the balloons carrying 950 g of apparatus reached heights of 26.5, 26.2, and 25.7 km. The average diameter of the balloons at the average bursting altitude was computed to be about 14 feet. Many of the balloons reached 15 feet in diameter and some 17 or so feet.

In August 1937 15 meteorographs of the Jaumotte type (manufactured in the United States) were also used. One of these instruments in each case was attached to the same balloon with a Fergusson meteorograph; the object, of course, being to compare the performance of the two types of meteorograph. Twelve of the Jaumotte type instruments were found and returned; six of these and approxi-

mately the top half of a seventh carried computable records. The agreement between the two records in each case and a comparison with the two-theodolite observations indicated that only one of the seven Jaumotte type instruments performed satisfactorily. This is in agreement with the performance shown by these instruments in other observations made during the summer of 1937. These two sets of observations are the first in which the Weather Bureau has had an opportunity to observe the performance of this type of instrument under actual working conditions. The excessive number of lost records due to obliteration can, no doubt, be reduced in the future by the method of smoking the record plate and by the use of a baffle plate in front of the record plate. This instrument is much less costly to manufacture than the Fergusson instrument and, while it has disadvantages, if it can be made satisfactory for use it will result in a great saving where a large number of observations, with a large loss of instruments, is required. Forty-nine of these meteorographs were released during the international month July 1938, each attached to the same balloon with a Fergusson meteorograph. Twelve of the observations were made with the view of studying the effect of insolation on the two instruments. Some very valuable data should be obtained when the records of those flights have been computed.

A higher rate of ascent was used in the August series than had been used previously. During that month the balloons were given a free-lift, after attaching equipment, of about 1,000 g. The average altitude at bursting during the August series (of those balloons which did not burst prematurely) was 23.5 km as compared to 22.9 km for those balloons carrying only one instrument during the November series and having a free-lift of about 650 g. It is generally believed that the greatest height would be reached by a balloon carrying a given weight when it has about the smallest free-lift which will cause it to rise. This would be expected from the fact that the maximum height reached is a direct function of the maximum possible size of the balloon; this maximum will be reached at a higher altitude the lower the free-lift at bursting. It is also known that at the low temperatures in the stratosphere the rate of flow of the rubber in the balloons is considerably decreased. Hence, a slow rate of ascent should allow the balloon to expand more before bursting than would be possible with a rapid rate of ascent. Another temperature factor which would be expected to operate in favor of a low rate of ascent is the insolation effect on a balloon during daylight flights. A nearly floating balloon would be ventilated very little so that its temperature might be expected to be raised by insolation to a value considerably higher than that of the surrounding air. A rapidly-rising balloon would be cooled on the outside by ventilation and on the inside by the nearly adiabatically expanding hydrogen, the temperature of which would tend to be considerably lower than that of the surrounding air in the stratosphere.

On the other hand, there are other factors which favor a rapid rate of ascent for the best altitude performance. Ozone, for example, has a pronounced deleterious effect on rubber. Hence, if it is present in important quantities in the upper atmosphere a balloon would be expected to

rise farther through a layer containing ozone if it rose rapidly. Another factor is that of the effect of time upon a highly expanded balloon. It may be that a balloon will expand to a given diameter if the expansion is accomplished in a given time, whereas if the time is increased (rate of expansion decreased) the balloon will burst at a smaller diameter. This factor would operate in a direction opposite to that of the effect of temperature on the rate of flow of the rubber and both are believed to be important.

Greater altitudes would be expected to be reached when the rate of ascent is such that the most favorable balance

series were found more than 150 miles from Omaha. The only one of these 9 which could be followed to a fair altitude with theodolites was that released on the 26th, which was followed to 10 km. Attention is called to the strong winds observed on that date. (See table 5.) The instrument was found 192 miles from Omaha. The balloon released on the 6th was followed to 6 km at which altitude the wind velocity was 45 m. p. s. This instrument was found 168 miles from Omaha. Such instances are indicative of the strong winds which would undoubtedly be frequently observed if the observations could be made in all kinds of weather to high altitudes.

One very favorable result of the use of a comparatively high rate of ascent during the August series was that most of the balloons could be followed to the bursting point with two theodolites. Twenty-four balloons were followed with two theodolites to heights of 20 km or higher. Nineteen observations of wind direction and velocity were made to 23 km, 13 to 24 km, 4 to 25 km, and 2 to 26 km. During July 1938 a still greater ascensional rate was used as well as larger balloons (700 g balloons) and observations of wind extended to considerably higher altitudes. During the latter month 15 observations of wind were made at 26 km and 4 at 29 km. The highest altitude to which a wind observation extended was 29,540 m., m. s. l. The balloon released on July 13, 1938, at 6:24 p. m. was observed with two theodolites to burst at that altitude. The wind data obtained during these series of observations constitute a large percentage of all wind data available for this country for heights above 20 km.

It is interesting to note at this point in connection with the observation of balloons at high altitudes that nearly all of the balloons followed with theodolites during the August and July series could be plainly seen with the naked eye at the bursting point. Some of the balloons became invisible to the unaided eye during part of the ascent on account of distance and low elevation angle but became visible again at high levels after a decrease in the distance out (due to being carried back in easterly winds) and an increase in the elevation angle. It was found that the balloons could nearly always be seen with the unaided eye when the elevation angle was about 25° or higher. After sunset at the ground the balloons rapidly grow brighter until they disappear in darkness 20 to 30 minutes later. A balloon cut off by darkness fades out quite rapidly, being completely obscured a minute or so after it begins to grow dim.

Tables 4, 5, 6, and 7 show the wind directions and velocities observed at the surface and each standard kilometer level during the June, November, August, and July series, respectively. The June and November series were not summarized on account of the small number of observations. The August and July observations, however, were summarized and the results are shown in figure 2 where the average wind velocities and directions have each been plotted against height. The average velocities were computed by the well-known "difference" method. The average directions were computed as resultants, giving each observed direction a weight of one, i. e., disregarding velocity.

It will be noted that the maximum velocity occurred at an altitude about 2 km lower than the mean observed height of the tropopause during August 1937. The mean height of the tropopause during July 1938 has not yet been computed but will probably be about 15 km, or somewhat lower than in August 1937.

This occurrence of the maximum mean velocity at an altitude somewhat below the mean height of the tropo-

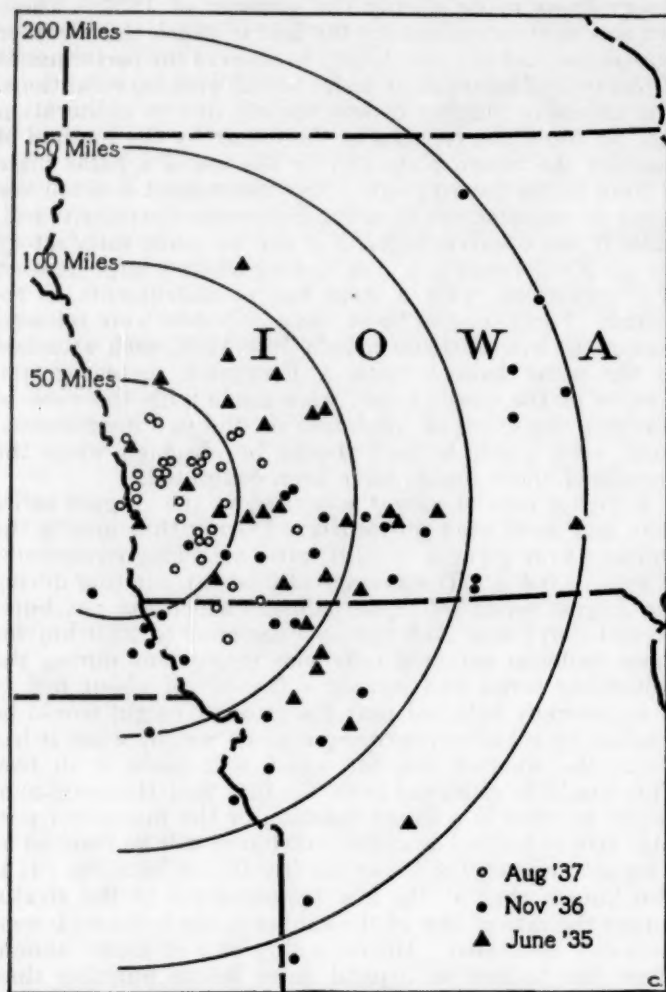


FIGURE 1.—Landing places of instruments released at Omaha, Nebr., in June 1935 (triangles), November 1936 (solid circles), and August 1937 (open circles).

between the various factors is struck. Experience has actually shown that the best altitude performance is obtained by using a fairly rapid rate of ascent—certainly not a very slow rate. Experience has also shown that the average heights reached on daytime flights are considerably greater than those reached at night. These two facts seem to indicate that the heating effect of insolation is important but that it is not the only important factor involved.

Figure 1 shows the landing places of the instruments released during the June, November, and August series of observations. The distances of the landing places from Omaha indicate in a general way the average wind velocities during each of the three months. It will be noted that 9 of the 35 recovered instruments of the November

pause is in agreement with the results of previous observations. The steady increase in velocity with altitude of the easterly winds above 21 km is worthy of note since it is a real phenomenon. That is, it is not caused by the frequent extension of westerly winds to altitudes in this range with the resultant low velocities in the region of the shift from westerly to easterly and the consequent reduc-

country to fully substantiate the theory of their prevalence. The two observations made during June 1935 at 21, 22, and 23 km likewise show easterly winds at these altitudes. On the other hand, during November 1936 five observations were made at 21 and 22 km, four at 23 km, and one at 24 km. Of all these observations none indicated easterly winds at 21 km, only one (NNE) at

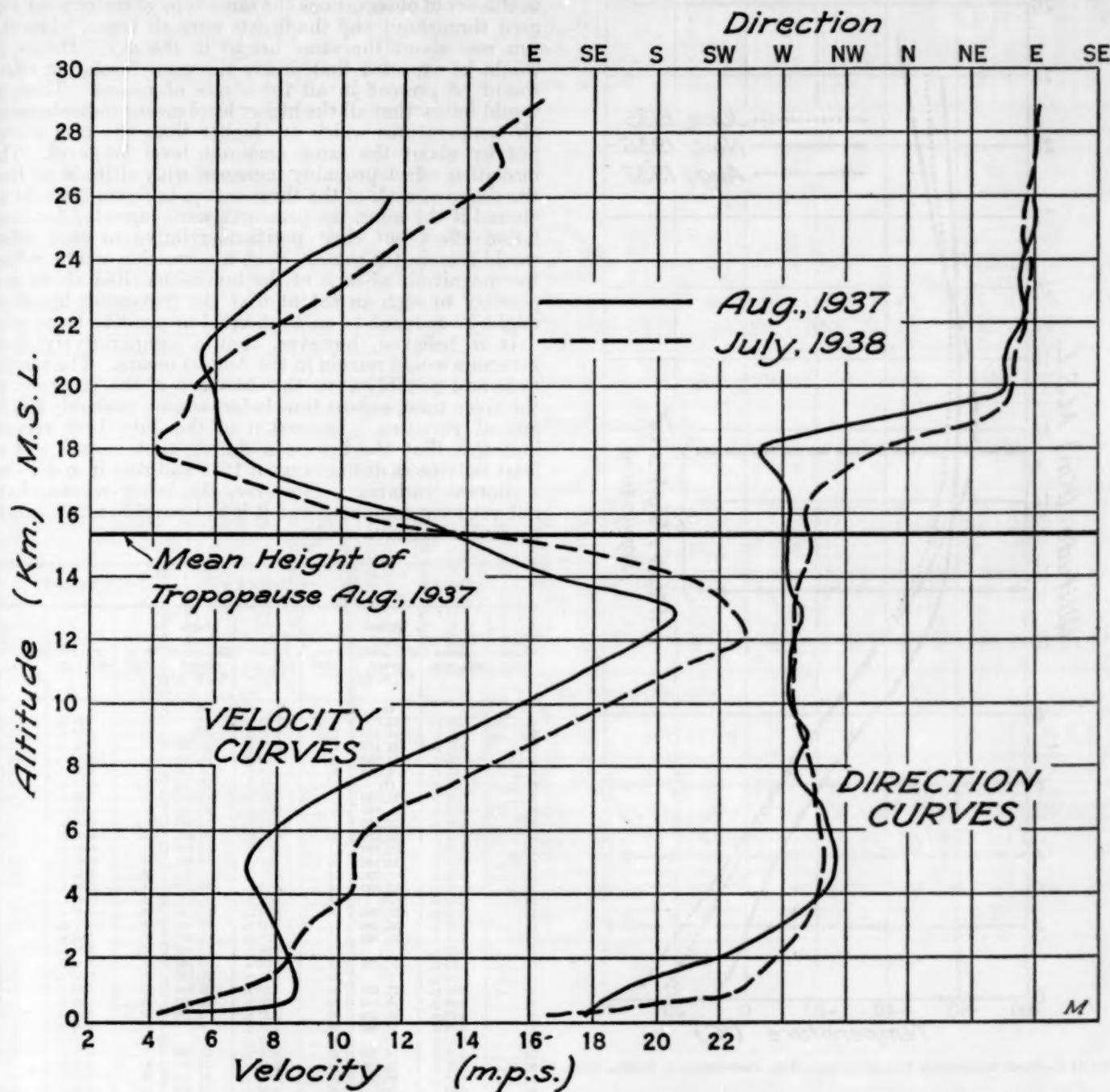


FIGURE 2.—Mean wind velocity (e) and direction (d) from sounding-balloon observations at Omaha, Nebr. (solid lines, August 1937, dashed lines, July 1938).

tion of the mean velocities at the first few standard heights above 21 km.

The prevailing easterly wind directions observed in the region of 20 km and above during the August and July series are especially worthy of note. Easterly winds at these altitudes and latitudes have been occasionally observed in the past but these are the first series of observations in which sufficient data have been gathered in this

22 km and one (ESE) at 23 km. The one observation at 24 km showed a NW wind. It would be interesting to know whether this reversal of wind direction, and of pressure gradient, is characteristic of the season or was true only during November 1936. It seems likely that the effect is seasonal in that easterly winds, if they occur at all, come in at higher altitudes in winter than in summer.

Figure 3 shows the mean temperatures for each of the three (June, November, and August) series plotted against height. November was the coldest of the three months from the surface up to 13 km and above 19 km. From 14 km to 19 km inclusive, however, August 1937 was the coldest of the 3 months. June 1935 was the

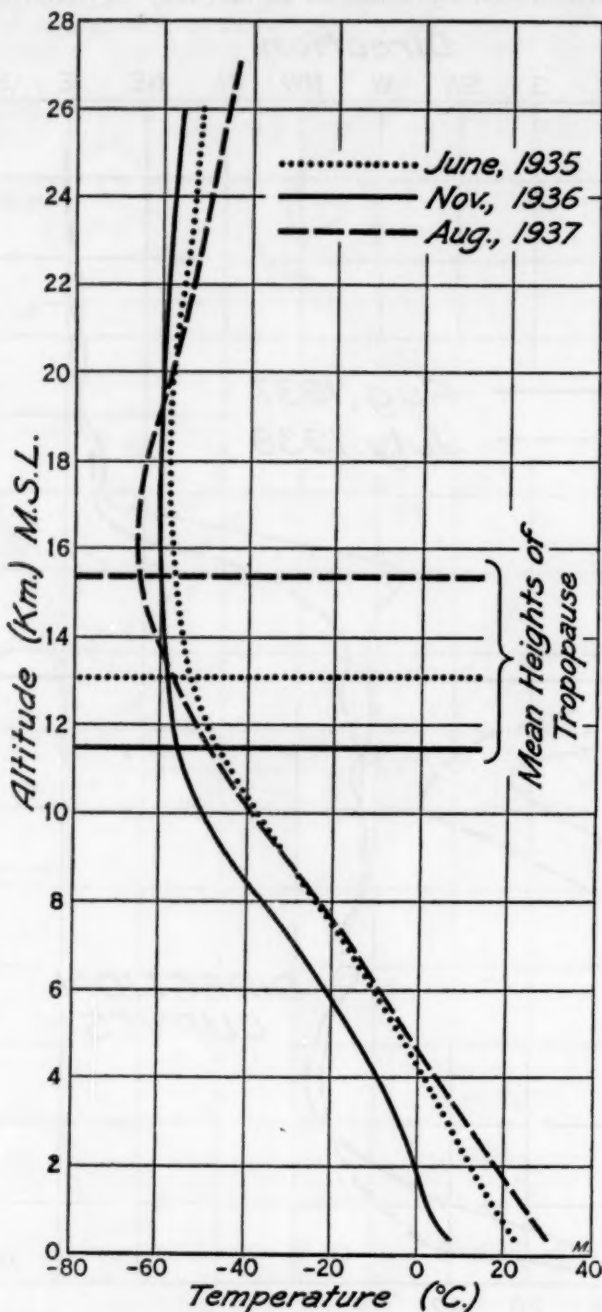


FIGURE 3.—Mean temperature from sounding-balloon observations at Omaha, Nebr.

warmest of the 3 months from 9 km to 20 km while August was the warmest from the surface to 8 km and above 20 km. It is very interesting to note the apparent seasonal trend in the mean temperatures at levels above 20 km, at which levels the temperatures, as at the surface and up to 8 km, were lowest in November and highest in August.

The large inversion indicated by the August means at high levels is likewise worthy of note. This inversion

amounted to 20.7° between the -65.7° C. mean at 16 km and the -45.0° C. mean at 26 km. The November inversion amounted to 5.3° between 17 and 26 km and the June inversion to 7.3° between 18 and 26 km. It is generally assumed that there is considerable error in the temperatures recorded at high levels on daytime flights due to the effect of insolation on the instrument. However, in this set of observations the same type of instrument was used throughout and the flights were all begun when the sun was about the same height in the sky. Hence, it would be expected that nearly the same insolation effect would be present in all three sets of means. Then, it would follow that all the higher level means indicate mean air temperatures which are higher than the true values but by about the same amounts, level for level. The insolation effect probably increases with altitude so that the shape of each of the three curves in figure 3 would be altered if the mean temperatures were corrected for insolation effect but their positions relative to each other would remain the same. Such a correction would reduce the magnitude of each of the inversions cited above and possibly to such an extent that the November inversion might be reduced to an isothermal or positive lapse rate.

It is believed, however, that a comparatively large inversion would remain in the August means. The magnitude and possibly even the existence of the inversion at the given time, a short time before sunset, probably has an annual variation. Inspection of the July 1938 records indicates that the inversion during that month was at least as large as during August 1937 and that it underwent a diurnal variation. However, the latter records have not yet been computed and it is not possible at present to present conclusive evidence.

TABLE 1			TABLE 2			TABLE 3		
Date June 1935	Time of release 90th mer.	Maxi- mum altitude of record M. S. L.	Date Nov. 1936	Time of release 90th mer.	Maxi- mum altitude of record M. S. L.	Date Aug. 1937	Time of release 90th mer.	Maxi- mum altitude of record M. S. L.
1.....	7:29 p.	22,030	1.....	4:32 p.	( <sup>1</sup> )	1.....	6:44 p.	6,100
2.....	7:08 p.	19,580	2.....	4:21 p.	( <sup>2</sup> )	2.....	6:16 p.	12,770
3.....	6:56 p.	22,340	3.....	4:24 p.	21,900	3.....	6:20 p.	22,400
4.....	7:05 p.	24,980	4.....	4:12 p.	18,820	4.....	6:10 p.	22,700
5.....	7:01 p.	8,340	5.....	4:25 p.	10,440	5.....	6:05 p.	14,010
6.....	7:04 p.	( <sup>3</sup> )	6.....	4:25 p.	25,440	6.....	6:00 p.	23,080
7.....	7:01 p.	21,030	7.....	4:27 p.	15,920	7.....	5:59 p.	6,200
8.....	6:56 p.	21,630	8.....	4:00 p.	22,600	8.....	6:03 p.	22,130
9.....	6:46 p.	26,100	9.....	4:13 p.	22,430	9.....	6:09 p.	19,570
10.....	7:01 p.	23,870	10.....	4:20 p.	26,560	10.....	6:00 p.	25,030
11.....	4:56 a.	9,420	11.....	4:06 p.	23,390	11.....	6:02 p.	( <sup>4</sup> )
12.....	6:57 p.	26,180	12.....	3:55 p.	24,860	12.....	6:05 p.	24,940
13.....	4:43 a.	8,290	13.....	3:57 p.	17,070	13.....	5:57 p.	( <sup>5</sup> )
14.....	6:56 p.	22,890	14.....	4:13 p.	24,520	14.....	5:50 p.	23,000
15.....	5:04 a.	( <sup>6</sup> )	15.....	4:08 p.	21,640	15.....	6:02 p.	24,400
16.....	6:50 p.	23,240	16.....	4:16 p.	19,780	16.....	5:40 a.	25,510
17.....	6:42 p.	22,900	17.....	7:15 a.	22,900	17.....	5:57 p.	22,470
18.....	6:44 p.	23,760	18.....	1:16 p.	5,610	18.....	5:43 a.	9,750
19.....	6:52 p.	( <sup>7</sup> )	19.....	4:36 p.	15,040	19.....	6:04 p.	20,040
20.....	6:52 p.	17,470	20.....	7:22 a.	26,190	20.....	5:45 a.	25,440
21.....	7:02 p.	( <sup>8</sup> )	21.....	4:41 p.	21,160	21.....	6:00 p.	23,530
22.....	6:40 p.	21,550	22.....	7:30 a.	24,990	22.....	5:43 a.	28,660
23.....	6:58 p.	19,940	23.....	4:28 p.	26,530	23.....	5:56 p.	21,790
24.....	6:39 p.	26,970	24.....	4:37 p.	2,270	24.....	5:46 a.	22,980
25.....	6:29 p.	17,940	25.....	4:21 p.	( <sup>9</sup> )	25.....	6:02 p.	22,740
26.....	6:36 p.	( <sup>10</sup> )	26.....	4:13 p.	( <sup>11</sup> )	26.....	5:51 a.	25,690
27.....	6:48 p.	19,800	27.....	4:10 p.	21,180	27.....	5:55 p.	22,330
28.....	6:31 p.	25,740	28.....	2:45 p.	14,470	28.....	5:56 p.	( <sup>12</sup> )
29.....	6:31 p.	26,330	29.....	11:43 a.	24,350	29.....	6:03 p.	( <sup>13</sup> )
30.....	6:47 p.	( <sup>14</sup> )	30.....	1:35 p.	18,420	30.....	5:59 p.	24,210
	6:18 p.	23,280		4:12 p.	14,450		5:59 p.	23,870
	6:41 p.	24,210		3:54 p.	18,180		6:02 p.	2,650
	6:49 p.	25,970		2:16 p.	22,550		6:29 p.	20,820
				4:07 p.	25,700		6:00 p.	21,370
				3:49 p.	( <sup>15</sup> )		6:03 p.	11,000
				4:00 p.	19,950		5:50 p.	23,900
				3:45 p.	19,820		5:50 p.	2,920
							5:51 p.	23,690

<sup>1</sup> Instrument not returned.

<sup>2</sup> Pressure pen failure.

<sup>3</sup> Clock stopped.

<sup>4</sup> Record obliterated.

<sup>5</sup> Pens tangled.

TABLE 4.—Wind directions and velocities from sounding-balloon observations at Omaha, Nebr., during June 1935

Date	ALTITUDE (KM, M. S. L.)											
	Surface	1	2	3	4	5	6	7	8	9	10	11
7	W 2	SW 5	WSW 6	WNW 7	WNW 14	WNW 23	WNW 30	W 32	W 39	W 39	W 39	W 42
8	S 5	S 7	WNW 7	NW 12	WNW 20	NW 18	NW 20	NW 23	NW 24	NW 25	NW 29	NW 30
12	SE 6	S 7	SW 5	WSW 6	W 9	NW 5	W 8	WSW 9	WNW 8	W 7	W 14	W 11
14	SE 6	ESE 6	SE 3	S 2	WSW 5	WSW 5	SSW 3	WSW 5	SW 9	SSW 13	SSW 13	SSW 15
15	S 6	S 12	SSW 15	S 11	SSW 14	SW 4	SEE 5	SSW 5	SSW 7	W 10	SW 12	WSW 15
20	N 3	N 4	NNW 5	NW 8	NNW 8	NNW 20	W 22	NNW 24	W 26	W 27	W 25	W 42
22	N 4	NNW 5	NNW 7	NNW 13	NNW 18	NW 21	NNW 24	NNW 24	NNW 22	NW 12	NW 15	WSW 26
25	NE 2	NE 5	NE 3	W 7	W 17	WSW 19	WSW 21	WSW 21	WSW 24	SW 19	WSW 25	WSW 26
26	SW 2	WSW 6	WNW 12	WNW 14	W 11	WNW 19	WNW 26	WNW 30	W 30	W 36	W 34	W 26
28	NE 2	NE 3	NW 6	WNW 7	NNW 10	NW 8	NNW 6	NNW 5	N 6	W 7	WSW 10	W 14

Date	ALTITUDE (KM, M. S. L.)												
	Surface	12	13	14	15	16	17	18	19	20	21	22	23
7	W 2												
8	S 5												
12	SE 6	W 19	W 20	W 28	WNW 30	W 29	WNW 25	NW 27					
14	SE 6	S 17	S 17	S 18	S 19	SSW 13	S 21	SSW 16					
15	S 6	WSW 21	WSW 24	W 22	W 15	WSW 17	WSW 19	WSW 18	WSW 6	WSW 6			
20	N 3	WNW 33	WNW 26	W 25	W 17	W 17							
22	N 4												
25	NE 2	SW 39	SSW 46	SW 42	SW 44	WSW 31	WSW 25	WSW 12	W 5	W 12	S 4	ESE 12	SE 4
26	SW 2												
28	NE 2	WSW 23	WSW 23	W 21	W 21	WSW 12	NE 4	NNW 6	ENE 2	NE 4	E 8	NE 7	E 7

TABLE 5.—Wind directions and velocities from sounding-balloon observations at Omaha, Nebr., during November 1936

Date	ALTITUDE (KM, M. S. L.)												
	Surface	1	2	3	4	5	6	7	8	9	10	11	12
3	NW 6	NW 7	NW 9	NW 11	NNW 8	N 9	N 15	NNE 29	NNE 31	NNE 19	W 10	WSW 21	SW 27
8	SW 4	WSW 12	WNW 15	NW 16	NW 17	NW 14	WNW 19	WNW 15	WNW 22	WNW 19	WNW 19	WNW 26	W 33
10	SSW 7	SW 16	WSW 13	W 14	W 11	W 11	WNW 11	WNW 14	WNW 11	NW 12	WNW 14	WNW 17	WNW 17
12	NNW 4	N 7	NW 9	NW 10	NNW 7	NE 11	NE 14	NE 15	NNE 18	NNE 20	N 12	NNW 11	NW 11
15	N 3	NNW 4	NW 7	NW 14	NNW 20	NNW 26	NNW 26	NNW 34	NNW 34	NNW 42	NNW 44	NNW 37	NNW 41
17	NW 1	NW 12	WNW 11	WNW 13	WNW 9	NW 11	WNW 14	W 18	W 17	WNW 15	W 12	W 13	WNW 11
18	N 4	NE 8	NNE 9	N 7	NNE 2	NNW 4	WNW 5	WNW 3	SSW 5	SW 4	W 8	W 13	W 16
19	SW 7	WSW 15	W 18	WNW 17	WNW 14	WNW 12	WNW 12	WNW 11	NW 8	NNW 15	N 9	NNW 14	
26	NNW 6	NW 10	NW 14	NNW 21	NNW 28	NNW 53	NNW 60	NNW 64	NNW 67	NNW 52	NNW 66		
27	SE 11	W 17	WNW 21	WNW 22	NW 23	NW 21	NW 20	NW 16	NW 21	NW 22	NW 27	NW 25	NW 31
28	SSE 4	SSE 4	WSW 3	WNW 8	W 15	W 15	WNW 16	WNW 15	WNW 19	WNW 18	WNW 20	WNW 15	WNW 21
30	SE 6	SSE 8	SW 8	WSW 9	W 13	W 17	W 19	W 19	W 21	W 22	W 27	W 23	W 28

Date	ALTITUDE (KM, M. S. L.)												
	Surface	13	14	15	16	17	18	19	20	21	22	23	24
3	NW 6												
8	SW 4	WNW 35	W 38	W 34	W 28	W 25	W 20	W 22	W 16				
10	SSW 7	W 20											
12	NNW 4	WNW 12	NW 11	WNW 13	WNW 14	NW 11	NW 10	NNW 7	NW 6	NW 10	WNW 5	WNW 8	
15	N 3	NNW 54	NNW 41	NNW 42	NNW 30	NW 33							
17	NW 1	W 11	WNW 13	NW 8	WNW 7	NW 14	N 6	WNW 3	NNE 3	NW 2	NNE 7	ESE 2	
18	N 4	W 17	WNW 12	WNW 10	NW 13	NW 9	NW 10	NW 7	N 6	WNW 9	N 6	NNW 6	NW 4
19	SW 7												
26	NNW 6												
27	SE 11	NW 24	NW 23	WNW 23	NW 22	NNW 15	NW 18	NW 20	NW 29	NW 25	NW 22	WNW 25	
29	SSE 4	WNW 24	WNW 27										
30	SE 6	W 28	W 20	W 27	W 25	W 26	W 21	W 10	W 14	W 18	WNW 17		

TABLE 6.—Wind directions and velocities from sounding-balloon observations at Omaha, Nebr., during August 1937

Date	ALTITUDE (KM, M. S. L.)												
	Surface	1	2	3	4	5	6	7	8	9	10	11	12
1.	SE 9	SSE 15	SSW 24	SW 13	SW 5	W 10	W 11	WSW 7	WSW 7	NW 5	W 7	W 10	WNW 15
2.	SE 4	SSE 11	SW 13	WSW 14	W 14	WNW 9	W 6	W 10	W 11	WSW 12	WSW 13	WSW 14	WSW 22
3.	N 4	NNE 6	N 4	NW 5	NW 8	WNW 11	W 17	W 21	WSW 31	WSW 31	WSW 31	WSW 30	WSW 28
4.	SE 3	S 2	WNW 5	NW 13	NNW 16	NNW 13	NNW 17	NNW 20	NNW 17	NNW 14	NNW 18	NW 22	NW 32
5.	SE 7	SSE 12	SW 9	WNW 6	NNW 6	NNW 15	NNW 14	NNW 12	NW 13	NW 25	NW 24	NW 29	WNW 25
6.	SE 5	S 9	SSW 11	SW 7	WNW 6	NW 4	NNW 8	NW 12	NW 16	NW 20	NW 21	NW 29	NW 24
7.	NW 2	N 5	NNE 6	N 16	NNW 16	NNW 13	NNW 8	NW 8	NW 14	WNW 14	WNW 22	WNW 26	WNW 20
8.	SE 5	SSW 4	SW 4	WNW 2	NW 7	NW 10	NW 6	WNW 6	W 11	W 20	W 29	W 35	W 33
9.	SE 4	N 7	NNW 12	NW 16	WNW 18	WNW 17	NW 21	NW 21	NW 22	NW 22	NW 21	NNW 23	NNW 29
10.	SE 6	SSW 8	WSW 12	NW 14	NNW 16	NW 17	NW 19	NNW 19	WNW 21	WNW 10	WNW 23	WNW 26	WNW 34
11.	SE 4	SSW 9	SW 6	W 1	WNW 5	NW 7	NNW 14	NNW 10	NNW 8	NW 10	NW 13	NW 14	NNW 16
12.	SE 9	SSE 13	SSW 12	WSW 7	WSW 6	WNW 5	W 5	WNW 2	SSW 7	WSW 6	WSW 8	W 10	WSW 12
13.	SE 6	S 12	SSW 15	SSW 15	WSW 7	NW 2	WNW 2	NW 2	WNW 6	W 9	WNW 10	W 10	W 7
14.	SE 4	S 18	SSW 11	WSW 4	ENE 5	W 1	E 2	NW 2	SSW 3	NNE 1	NNE 2	NNE 2	NE 4
15.	SE 4	S 11	SSW 8	WSW 4	ENE 3	NNE 6	E 2	NNW 2	NE 4	NNE 4	ESE 3	SSE 2	SSW 4
16.	NE 7	ESE 8	SSW 3	NW 5	SSW 6	N 5	NNW 3	WNW 3	W 6	WNW 12	W 13	WSW 17	WSW 15
17.	S 7	SSE 11	SW 12	SW 8	WSW 7	WSW 7	WSW 8	SW 14	WSW 13	WSW 14	WSW 20	WSW 21	WSW 20
18.	E 6	SSE 6	SSW 4	SE 5	SSE 5	NW 1	WSW 7	W 13	WSW 19	WSW 24	SW 24	SW 34	WSW 27
19.	N 4	NNE 8	N 5	NNW 16	N 13	WNW 5	WNW 7	WSW 9	WSW 19	WSW 24	SW 24	SW 34	WSW 27
20.	N 4	ENE 8	NNW 11	NNW 12	N 11	NNW 5	NNW 6	NNW 7	NNW 7	NW 8	WSW 16	W 23	WSW 34
21.	E 2	ENE 2	NNE 5	N 6	E 7	ENE 9	NNW 8	NNW 9	NNW 8	NNW 11	WNW 11	W 12	W 24
22.	SE 6	SE 4	SE 4	ESE 6	E 7	ENE 3	NNW 6	NNW 5	WNW 6	WNW 9	NW 13	WNW 10	W 16
23.	SE 6	SSE 9	S 9	SSE 7	S 3	ENE 3	NNW 6	NNW 7	WNW 5	NW 3	WNW 4	NW 13	NW 23
24.	SE 8	SSE 11	SSW 10	SSW 8	S 8	E 1	W 1	NNW 2	W 3	NNW 5	WNW 13	NW 16	NW 17
25.	SE 4	SSE 6	SW 3	NW 4	NW 10	NW 8	NW 12	W 21	WNW 16	W 17	WNW 18	WNW 16	WNW 17
26.	E 1	NE 1	NW 3	NW 9	N 7	N 6	NNW 9	NW 8	NW 20	NW 28	WNW 28	WNW 29	WNW 27
27.	S 3	SSE 5	W 3	SW 1	WNW 2	NW 3	NNW 8	NW 11	NW 14	NNW 17	NW 17	NW 24	NW 21
28.	SE 8	S 14	S 13	SW 10	W 1	SW 3	SSW 1	WSW 4	WSW 8	WSW 8	W 11	WNW 12	WNW 11
29.	SE 6	SSE 11	SSW 7	WSW 8	SW 6	SSW 7	SSW 7	SW 7	SW 9	SW 8	SW 6	WSW 3	WSW 6
30.	SE 6	SSE 10	SSW 9	SW 6	SW 3	W 5	SW 4	S 7	SSW 3	SSE 2	SE 3	SE 5	ESE 3
31.	SE 5	SSE 9	S 4	SSW 4	S 3	WSW 2	S 4	SSW 6	SSW 6	S 6	S 8	SSE 3	S 4

Date	ALTITUDE (KM, M. S. L.)												
	Surface	14	15	16	17	18	19	20	21	22	23	24	25
1.	SE 9	NW 14	N 13	NNE 7	SE 7	SE 5	SSE 7	E 5	ENE 7	ENE 9	ENE 7	ENE 7	
2.	SE 4	SW 19	W 12	WSW 5	W 7	W 3	NNW 1	ENE 9	ENE 7	ENE 11			
3.	N 4	SW 38	WNW 27	W 22	N 8	NW 3	ENE 11	ENE 4	NE 8	E 7	ENE 8	NNE 11	
4.	SE 3	NW 38	WNW 27	W 22	N 8	NW 3	ENE 11	ENE 4	NE 8	E 7	ENE 8	NNE 11	
5.	SE 7	WNW 17	W 13	W 11	SSW 7	SW 8	WNW 3	ESE 6	E 6	E 8	E 7		
6.	SE 5	WNW 17	W 13	W 11	SSW 7	SW 8	WNW 3	ESE 6	E 6	E 8	E 7		
7.	NW 2	W 18	W 18	WNW 10	SW 6	W 3	E 1	E 7					
8.	SE 5	W 22											
9.	NW 4	NW 20	NW 11	W 5	WNW 10	NW 7	N 4	ESE 2	ESE 7	SE 3	E 8	E 8	
10.	S 6	NW 23	NW 17	WNW 18	WNW 10	WNW 11	NW 12	NW 9	N 5	NNW 2	NE 5	ENE 6	E 8
11.	N 4	NW 13	WNW 10	NW 17	NNE 1	SW 6	NW 5	NNW 4	NE 4	E 5	ENE 4	NE 7	ENE 9
12.	SE 9	WSW 12	WSW 11	W 11	NW 4	SW 5	NE 4	SE 3	NE 1	E 6	E 5	E 6	
13.	S 6	W 6	WSW 9	WSW 5	S 5	SSE 4	W 4	NNW 2	NE 7	ENE 7	E 5		
14.	SE 4	SW 4	W 5	WSW 7	WSW 9	SW 2	NW 5	SSE 4	N 4	NE 8	NE 6	ESE 7	E 10
15.	SE 4	W 6	WSW 5	W 6	WNW 5	SW 3	N 4	SE 3	NNW 3	NNE 5	NE 9		
16.	NE 7	W 11	WSW 6	WNW 11	WNW 7	WNW 9	NNW 6	NW 3					
17.	S 7												
18.	E 6	SW 18	SW 7	W 8	WNW 4	SW 9	NE 4	SW 10	W 6	S 6	S 5		
19.	N 4	WSW 25	WSW 20	WSW 7	WSW 8	WSW 5	WNW 9	SSW 7	E 2	E 5	ENE 11		
20.	N 4	WSW 30	W 20	W 15	WSW 16	W 9	W 7	W 5	NNW 4	SSE 1	ESE 6	ESE 5	ESE 6
21.	E 2	W 20	W 18	W 11	W 8	W 5	N 5	NNW 4	N 2	E 6	E 4		
22.	SE 6	WNW 15	WNW 13	WNW 13	WNW 7	WNW 5	N 4	NNW 3					
23.	SE 6	WNW 17	W 11	W 14	W 2	S 3	SSW 4	WNW 4	SSE 1	ENE 6	E 6	NE 8	
24.	SE 8	WNW 15	WNW 12	WNW 12	WNW 7	SW 4	WSW 4	W 4	SE 3	NNE 3	NE 8	E 10	
25.	SE 4	WNW 17	NW 11	WNW 13	WSW 7	WNW 5	N 7	NE 4	NE 5	E 4			
26.	E 1	NW 15	NW 23	NW 13	NNW 5	NNW 2	N 1	NE 5	E 6				
27.	SE 8	WNW 8	NW 6	WNW 7	SSW 4	WSW 3	ESE 2	E 4	SSE 4	ENE 3			
28.	SE 6	SW 7	SSW 6	SSW 8	SSW 12	W 4	S 3	SSE 7	ESE 6	ESE 3	SE 5	E 5	
29.	SE 6	WSW 6	SSW 11	SW 12	WSW 8	S 11	WSW 6	ENE 3	E 3	ESE 5	ESE 3	SE 8	
30.	SE 6	SSE 10	SSW 9	WSW 10	WSW 4	W 7	ENE 4	ESE 1	SE 2	NE 4	NE 5	ENE 7	

TABLE 7.—Wind directions and velocities from sounding-balloon observations at Omaha, Nebr., during July 1938

Date	ALTITUDE (KM, M. S. L.)														
	Surface	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	E 6	SE 12	SSE 10	SSW 4	WSW 6	W 10	W 10	WSW 10	WSW 14	WSW 17	WSW 19	WSW 23	WSW 29	WSW 30	SW 29
3	SE 6	SSE 9	SSW 9	SW 3	WSW 4	SW 5	WSW 4	WSW 5	WSW 6	WSW 10	WSW 14	WSW 19	SW 22	SW 23	SW 23
4	S 4	S 10	S 9	SSW 7	SSW 4	SSW 4	SSW 6	SSW 6	W 12	SW 14	SW 16	SW 18	SW 26	SW 19	SW 21
5	S 4	S 12	S 8	S 3	W 3	WSW 6	SW 11	SW 8	WSW 14	SW 17	SW 24	WSW 21	SW 26	SW 28	SW 25
6	W 4	WSW 4	W 8	W 10	WSW 14	WSW 15	W 15	W 17	WSW 25	SW 34	SSW 37	SSW 44	SW 45	SW 32	SW 25
7	NW 3	WNW 3	WNW 8	NW 13	NW 12	NW 13	NW 18	NNW 18	NNW 22	NNW 21	NNW 25	NW 23	WNW 19	WNW 21	WNW 16
8	S 6	S 12	SW 16	W 14	WNW 12	NW 9	NW 15	WNW 15	WNW 18	WNW 20	WNW 24	WNW 26	WNW 22	WNW 17	W 18
9	E 2	E 2	SSW 5	W 3	WNW 7	WNW 11	NW 13	NW 13	NW 17	NW 21	WNW 24	W 25	W 30	W 30	WNW 22
10	S 3	SW 8	SW 9	WSW 9	SW 8	W 5	W 4	W 6	W 9	W 7	W 7	W 10	WNW 13	W 13	WNW 17
11	S 4	N 6	SW 10	SW 9	W 10	NW 7	N 6	NW 7	WNW 10	W 12	WSW 14	W 17	W 17	W 18	WNW 16
12	N 8	N 10	NW 13	NW 20	NW 21	NW 17	NW 16	NW 16	NW 19	WNW 17	WNW 16	W 12	WNW 15	W 15	WNW 28
13	N 4	N 6	NW 8	NNW 9	NNW 11	NNW 16	NW 13	NW 14	NW 12	WNW 14	WNW 17	WNW 20	WNW 21	NW 25	NW 23
14	SE 4	SSW 5	WSW 6	NW 6	NW 7	NW 8	NW 10	W 9	WNW 11	WNW 12	W 12	W 15	WNW 16	WNW 20	WNW 22
15	E 4	ENE 6	NNE 9	NNE 11	N 8	NNE 6	NNW 6	NNW 8	NW 9	WNW 11	W 12	WNW 13	WNW 14	NW 16	WNW 14
16	S 2	SSW 3	SW 2	SW 2	WSW 4	W 4	NNW 6	NNW 8	WNW 13	WNW 17	WNW 15	WNW 18	WNW 23	WNW 23	W 18
17	N 6	N 7	N 5	NW 8	NW 12	NW 5	NNW 11	NW 13	NW 14	NW 14	WNW 15	W 20	W 29	WNW 25	WNW 25
18	NE 3	ENE 4	NNE 4	NNW 6	NW 10	NW 12	NW 12	NW 15	WNW 15	W 19	W 20	W 24	W 26	W 29	W 25
19	E 4	NW 6	NW 11	WNW 17	WNW 20	WNW 12	WNW 9	WNW 21	WNW 24	WNW 19	WSW 17	WNW 22	WNW 26	WNW 30	NW 20
20	N 4	NW 6	NW 9	NW 11	NNW 15	NW 18	NW 16	NW 15	NW 19	NW 19	WNW 20	WNW 22	WNW 26	WNW 30	NW 20
21	SE 7	S 11	SW 9	WSW 10	NNW 8	NW 7	WNW 6	NW 9	NW 8	NNW 6	NNW 8	NNW 8	NNW 8	NNW 10	WNW 15
22	S 5	SW 12	SW 10	WNW 8	WNW 8	WNW 8	W 4	W 9	WSW 9	WSW 10	SW 9	WNW 9	WNW 16	WNW 18	W 14
23	N 6	ENE 4	WSW 6	SW 6	WSW 11	WSW 11	W 8	WNW 11	W 12	WSW 18	WNW 19	W 16	WNW 22	WNW 19	WNW 19
24	N 2	NNW 3	NW 9	NNW 12	NW 15	NW 11	NW 15	WNW 16	WNW 18	W 21	W 24	W 28	W 24	W 24	W 22
25	N 7	NNW 7	NNW 9	NNW 11	NNW 14	NNW 22	NNW 21	NNW 19	NW 13	NW 12	NW 16	NW 18	NW 17	NW 16	NW 22
26	SE 2	NNW 4	N 9	N 11	NNW 16	NNW 18	NNW 14	NNW 16	NNW 21	NNW 26	NNW 37	NNW 39	NNW 35	NNW 27	NW 24

Date	ALTITUDE (KM, M. S. L.)														
	Surface	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2	E 6	NE 16	WSW 6	NW 3	ESE 2	ENE 9	E 10	ESE 6	ESE 5	ENE 6	E 9	ENE 11	-----	-----	-----
3	SE 6	WSW 20	SSW 3	SW 3	W 2	ESE 9	ENE 4	E 4	E 9	-----	-----	-----	-----	-----	-----
4	S 4	SW 15	WSW 11	SSW 6	SE 3	E 4	E 7	ENE 10	E 8	E 12	E 12	-----	-----	-----	-----
5	S 4	SW 17	SW 10	WSW 6	S 8	NE 2	ENE 3	E 6	ESE 5	E 7	E 10	ENE 12	E 15	E 15	E 15
6	NW 3	WNW 7	WNW 6	WNW 3	N 5	NE 7	ENE 6	ENE 7	ENE 6	ENE 6	ENE 11	E 15	E 17	E 16	E 14
7	S 6	WNW 13	NW 10	NNW 4	NNE 1	NE 3	ESE 7	E 7	E 9	E 14	E 12	E 11	E 14	E 14	E 15
8	E 2	NW 14	NW 9	NE 2	ENE 1	E 5	E 3	ENE 7	E 12	ESE 7	E 8	ENE 10	E 14	E 14	ENE 13
9	S 3	NW 8	SSW 3	N 4	NE 2	ENE 8	ENE 7	-----	-----	-----	-----	-----	-----	-----	-----
10	S 4	NW 13	WNW 8	NW 7	NE 6	SE 6	NE 5	ENE 9	E 12	ENE 6	E 12	ENE 13	E 12	E 11	-----
11	N 8	NW 21	WNW 6	NW 10	SE 5	NNW 10	ENE 8	E 6	ENE 6	E 8	E 9	ENE 12	ENE 16	ENE 14	E 18
12	N 4	NW 23	NW 13	NW 7	NNW 3	NE 5	WSW 6	NNE 5	NE 7	E 8	E 8	ENE 13	-----	-----	-----
13	SE 4	WNW 18	NW 16	WNW 10	WNW 7	NNE 4	NE 7	ESE 4	NE 5	E 7	ENE 9	E 10	E 12	E 10	-----
14	N 4	NW 23	NW 13	NW 7	NNW 3	NE 5	WSW 6	NNE 5	NE 7	E 8	E 8	ENE 13	-----	-----	-----
15	SE 4	WNW 18	NW 16	WNW 10	WNW 7	NNE 4	NE 7	ESE 4	NE 5	E 7	ENE 9	E 10	E 12	E 10	-----
16	E 4	NW 11	WNW 8	NW 7	NNW 5	WNW 4	NNE 5	ENE 5	ENE 12	-----	-----	-----	-----	-----	-----
17	S 2	W 24	WNW 12	WNW 11	NW 6	E 2	ENE 4	ENE 6	NE 7	E 13	E 12	E 13	E 14	E 14	ENE 12
18	N 6	WNW 14	W 12	NW 9	W 3	NE 3	ENE 3	E 5	ENE 7	E 10	E 10	E 11	-----	-----	-----
19	N 3	WNW 24	WNW 13	WSW 10	WNW 4	W 6	NW 5	NE 7	E 10	ENE 11	E 12	E 14	E 14	E 17	E 19
20	NE 3	WNW 24	WNW 13	WSW 10	WNW 4	W 6	NW 5	NE 7	E 10	ENE 11	E 12	E 14	E 14	E 17	E 19
21	E 4	WNW 19	NW 12	WNW 6	WNW 7	NNE 4	E 4	NE 5	E 8	ENE 10	E 12	ESE 14	E 13	E 16	E 16
22	N 4	WNW 15	NW 10	NW 7	WNW 4	NNE 3	E 4	ENE 6	ESE 7	ENE 8	E 12	E 12	E 11	E 12	-----
23	SE 7	WNW 15	NW 10	NW 7	WNW 4	NNE 3	E 4	ENE 6	ESE 7	ENE 8	E 12	E 12	E 11	E 12	-----
24	S 5	W 10	W 7	NW 6	NNE 2	ENE 4	E 5	E 5	E 6	E 10	E 10	ENE 8	E 13	E 18	-----
25	N 6	W 7	W 11	WNW 8	SSW 2	ENE 1	E 3	-----	-----	-----	-----	-----	-----	-----	-----
26	N 2	WNW 20	W 21	WNW 12	NNW 1	NNE 1	E 2	NE 5	NE 10	ENE 13	E 15	E 10	E 18	NE 17	NE 16
27	N 7	NW 23	NE 7	NW 7	E 7	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
28	SE 2	W 10	NW 11	WNW 8	W 4	E 2	ENE 3	NE 7	ENE 7	E 10	E 11	ENE 14	E 15	ESE 13	ESE 14

# DISTRIBUTION OF AIR-MASS TYPES AND FREQUENCY OF CHANGE IN THE WESTERN UNITED STATES DURING 1937-38

ARCH C. GERLACH

[University of Washington, Seattle, Wash., May 1938]

In a study of air masses and their movements in the western United States, a table was made showing the air-mass type present each day at Seattle, Spokane, Williston, Salt Lake City, San Francisco, and Los Angeles during the year March 1, 1937, to March 1, 1938. This year had a slight plus departure in both temperature and precipitation for a majority of the stations. The data were taken from manuscript maps at the Seattle Airport Weather Bureau where the air masses and fronts were plotted according to analyses made at Washington, D. C. The record is incomplete only to the extent that analyses for the western United States were usually omitted on Sundays and holidays.

The number of days on which each air-mass type was present at each station, expressed in percent of the year, is shown in table 1, and gives some indication of the areal distribution of types over the western United States during the year.

Except for the outstanding preponderance of NPP air at every station but Williston, there is nothing about the distribution of air-mass types which is not in conformity with what is normally to be expected considering latitude and distance from the sea.

Pp air was more prevalent at Seattle than toward the interior or toward the south. NPP was most extensive at the southwestern and interior stations, where the low latitude or interior position is conducive to modification of the Pp air mass properties.

In contrast with the prevalence of Pp and its transitional phase on the Pacific coast, Pc and its transitional phase predominated at interior stations. Pc air was most prevalent at the northern interior station, Williston, and rapidly decreased in extent toward the Pacific coast and toward the south. The distribution of NPC air closely resembled that of the true Pc, except that it was present in larger proportion at all stations but Williston. It was peripheral to the Pc air on the west and south, as NPP was peripheral to the Pp air on the east and south. Apparently Pc came in contact with Pp or NPP air most frequently in the vicinity of Spokane, where there was the highest percent of Pc interspersed with unabsorbed or unmixed layers of Pp or NPP air.

Tropical Pacific air was found mainly at Los Angeles, nearest its source region, and decreased in extent northward and toward the interior. Aloft, the drier S was also most prevalent at Los Angeles, with a marked decrease in occurrence toward the northern coastal cities, but a comparatively small decrease over the interior plateau. S was present aloft 7 percent of the year at Salt Lake and 5 percent as far north as Williston, compared with 3 percent at San Francisco and 2 percent at Seattle.

The relation between season and extent of different air-mass types is illustrated by a series of graphs for January, April, July, and October, the midmonths of the four seasons, figure 1.

It is apparent that NPP air was predominant at all seasons, but most extensive in the spring, with a secondary in the fall season. Tropical air was conspicuous only in the spring and early summer. Pc air was most prevalent in the winter, but did not reach as far south even as Salt Lake City or San Francisco during January. NPC

was least extensive in winter, being present only at Williston in January, while during the summer and especially the fall season it was found at all stations.

The greatest variety of air-mass types occurred at all stations in the spring, with a secondary in the fall, while the greatest uniformity in type was during the winter with a secondary in summer.

The areal distribution of frequencies of change is shown in table 2, which gives the number of changes of air-mass type that occurred each month at each of the six stations. From the annual totals of this table it appears that the greatest frequency of change was at the interior and northern stations, with the number of changes diminishing toward the coast and southward. The monthly totals show that April had the greatest number of changes (97) followed by September (88), while the fewest occurred in January (23) followed by July (48).

Except for September, these are the midmonths of the four seasons, and therefore should be indicative of air-mass movements during these periods. It is not astonishing to find that fewer changes occurred in January and July, when there was the least variety of air-mass types, nor that most changes occurred during the transitional seasons when there were the greatest number of air-mass types. These changes, which occurred in the transitional seasons when Pp and Tp air was most prevalent, became much less frequent in January and July when the more predominant NPP and Pc air masses had reached their maximum extent. There were fewer changes in the fall than in the spring because the change from summer to winter is less abrupt than the change from winter to summer which is attended by movements from more radically different surface conditions; i. e., bare ground, snow, ice, dormant vegetation, etc.

TABLE 1.—Percentage of year during which different types of air masses prevailed

	Pp	NPP	Pc	NPC	Pc-Pp	Tp	S
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Seattle.....	33	44	6	10	4	2	1
Spokane.....	27	45	8	14	5	0	0
Williston.....	6	32	32	22	4	1	1
Salt Lake City.....	18	2	2	17	4	3	3
San Francisco.....	26	1	1	7	3	6	1
Los Angeles.....	18	1	1	6	2	9	4

TABLE 2.—Number of changes of air mass

	Williston	Spokane	Salt Lake City	Seattle	San Francisco	Los Angeles	Monthly totals
March.....	15	12	15	8	10	10	70
April.....	21	18	17	13	14	14	97
May.....	19	13	13	13	9	10	77
June.....	13	11	12	10	11	10	67
July.....	13	9	9	7	5	5	48
August.....	13	16	10	17	13	11	80
September.....	16	15	14	17	12	14	88
October.....	16	14	15	11	11	11	78
November.....	10	15	11	14	9	7	66
December.....	11	11	12	13	9	11	67
January.....	15	2	1	2	2	1	23
February.....	7	15	11	10	10	10	63
Annual totals.....	169	151	140	135	115	114	-----

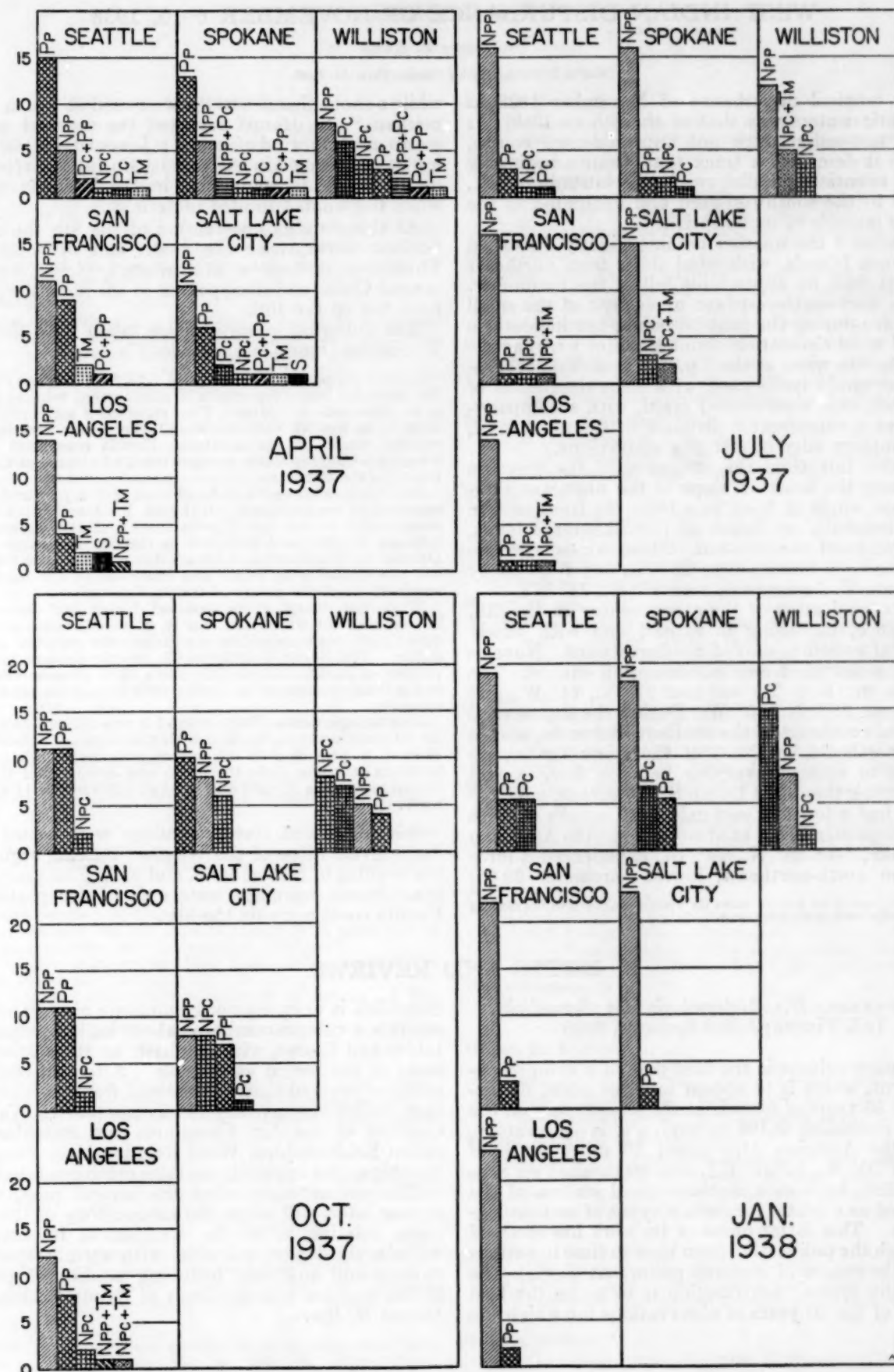


FIGURE 1.—Frequency of air-mass types at six stations in January, April, July, and October.

## WEST INDIAN DISTURBANCE OF NOVEMBER 6-10, 1938

By WILLIS E. HURD

[Marine Division, Weather Bureau, December 1938]

The only tropical disturbance of November 1938 in North Atlantic waters was that of the 6th to 10th. It pursued an unusual, though not unprecedented course, inasmuch as it described a track that, from a beginning south of the twentieth parallel, reached to latitude  $24^{\circ}$  N., then turned to the southwestward and dissipated in the approximate latitude of its inception.<sup>1</sup>

On November 4 the weather became slightly disturbed in the Leeward Islands, with wind shifts from northeast to south, but with no appreciable fall in the barometer. There was a west-northwestward movement of the small disturbed wave during the next 48 hours, but indications of organized wind circulation about a center were incomplete until the 6th when at the 7 p. m. (E. S. T.) observation, a center could be located, with some depression of the barometer, over west-central Haiti, with accompanying squalls at a considerable distance to the northward, along the southern edge of a strong anticyclone.

Even before this time the steepness of the pressure gradients along the southern slope of the high was sufficient to cause winds of fresh gale force (8) from east to northeast directions, southeast of the Bahama Islands, during the night of the 5th-6th. These winds were reported by the S. S. *Coamo*, near  $23^{\circ}$  N.,  $68^{\circ}$  W., and by the S. S. *Susan V. Luckenbach*, near  $25^{\circ}$  N.,  $74^{\circ}$  W.

After the organization of the storm center on the 6th, the disturbance, increasing in extent, and with slowly falling central pressure, moved northwestward. November 7 was the stormiest day in connection with it. The center at 7 a. m. (E. S. T.) was near  $21^{\circ}$  N.,  $74^{\circ}$  W., and at 7 p. m. near  $22\frac{1}{2}^{\circ}$  N.,  $75^{\circ}$  W. During the day several ships east and southeast of the southern Bahamas, and to the north, northeast, and east of the storm center, reported gales of strength varying between force 8 and force 11. Among these, the Dutch S. S. *Bacchus*, near  $24^{\circ}$  N.,  $69^{\circ}$  W., had a force-10 east gale, with squalls of force 11, lowest barometer 29.68, at about 4 a. m.; the American S. S. *Arizonan*, near  $24^{\circ}$  N.,  $74^{\circ}$  W., experienced a force 10 gale from north-northeast, lowest barometer 29.65;

<sup>1</sup> Chart IX in this issue of the REVIEW shows the weather conditions on the morning of the 8th, and also the track of the disturbance.

while a short distance to the westward at 1 p. m. the Panamanian S. S. *Maravi* reported the severest gale of the storm, a north wind of force 11, barometer 29.63. Lessening gales occurred in the vicinity during the afternoon and night, and until some time in the forenoon of the 8th, when the winds subsided materially.

At the morning observation of the 8th the center was farthest north, near the south end of Andros Island. Thereafter it took a southwesterly trend across west-central Cuba, and disappeared in the northwestern Caribbean Sea on the 10th.

The following quotations are taken from the report of Forecaster Dunn, Jacksonville, Fla.:

During the passage of this storm \* \* \* on the 7th \* \* \* San Salvador Island reported a 50 mile current velocity at their 1:30 p. m. observation. Miami, Fla., reported a maximum wind of 28 m. p. h. on the 8th and somewhat higher winds were reported from exposed places on the southeast Florida coast and Keys. The lowest reported reputable pressure was 29.54 inches at Great Ragged Island in the Bahamas.

Due to repeated warnings small craft kept in port and damage was reported to be negligible. However, wind and wave erosion was considerable on the east Florida coast and damage was estimated between \$75,000 and \$100,000 in the St. Augustine area alone. Damage by this storm and by another northeaster a few days later will necessitate some repair and extension on the land end of the north jetties at the mouth of the St. Johns river.

While the strong winds reported during this disturbance were largely gradient winds and mostly north of center, much less frequent but occasionally heavy squalls were reported south of the center. The Cuban Telephone Co. reports damage to lines in the vicinity of Baracoa on the 7th, also a 35 to 50 mile wind at Antilla and a heavy rainstorm at Caimaneira during the afternoon of the same day.

Due to high winds off the ground it was difficult to obtain upper air information in connection with this storm. Velocities of 35 to 45 m. p. h. prevailed off the surface over the Florida peninsula for 36 hours or longer while the storm was moving over the Bahamas. Miami reported a 52 mile east wind at 3,000 feet at 11 a. m., November 7.

Advisories and storm warnings were issued from the Jacksonville office of the Weather Bureau, beginning with the evening of November 6, and ending on the night of the 8th. Storm warnings were ordered for portions of the Florida coast early on the 8th.

## NOTES AND REVIEWS

F. STEINHAUSER. *Die Meteorologie des Sonnblicks*, I. Teil. Vienna; Julius Springer, 1938

This 180-page volume is the first part of a comprehensive treatment, which is to appear in three parts, discussing the first 50 years of records at the observatory on the peak of the Sonnblick (3,106 meters). This observatory, located in the Austrian Alps about 50 miles south of Salzburg ( $47^{\circ}03'$  N.,  $12^{\circ}57'$  E.), was established on September 2, 1886, both as a meteorological station of the first order and as a center for certain types of meteorological research. This latter phase of its work has received notice through the publication from time to time in various journals of the results of research performed there. The purpose of the present contribution is to make the best possible use of the 50 years of observations for which the

Sonnblick is unique among mountain observatories. The result is a volume composed about half of text and half of tables and figures, with emphasis on the statistical treatment of the record as a whole. A topical outline of the material covered may be obtained from the chapter headings, which are as follows: Temperature, Water Vapor Content of the Air, Cloudiness and Sunshine, Precipitation Relationships, Wind Relationships, Pressure Relationships. An appendix contains extensive tabular matter.

The author states that the second part, which will appear later, will cover the meteorology of the mountain mass, relating it to the weather of its surroundings, while a third part will deal with certain special observations and analyses, including studies of periodicities in the weather and problems of dynamic climatology.—*Horace R. Byers.*

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By AMY P. LESHER

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## SOLAR OBSERVATIONS

[Meteorological Research Division, EDGAR W. WOOLARD, in charge]

## SOLAR RADIATION OBSERVATIONS, NOVEMBER 1938

By IRVING F. HAND

Measurements of solar radiant energy received at the surface of the earth are made at eight stations maintained by the Weather Bureau, and at nine cooperating stations maintained by other institutions. The intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) at all these stations by self-registering instruments; pyrheliometric measurements of the intensity of direct solar radiation at normal incidence are made at frequent intervals on clear days at three Weather Bureau stations (Washington, D. C., Madison, Wis., Lincoln, Nebr.) and at the Blue Hill Observatory of Harvard University. Occasional observations of sky polarization are taken at the Weather Bureau stations at Washington and Madison.

The geographic coordinates of the stations, and descriptions of the instrumental equipment, station exposures, and methods of observation, together with summaries of the data, obtained up to the end of 1936, will be found in the MONTHLY WEATHER REVIEW, December 1937, pp. 415 to 441; further descriptions of instruments and methods are given in Weather Bureau Circular Q.

Table 1 contains the measurements of the intensity of direct solar radiation at normal incidence, with means and their departures from normal (means based on less than 3 values are in parenthesis). At Madison and Lincoln the observations are made with the Marvin pyrheliometer; at Washington and Blue Hill they are obtained with a recording thermopile, checked by observations with a Marvin pyrheliometer at Washington and with a Smithsonian silver disk pyrheliometer at Blue Hill. The table also gives vapor pressures at 8 a. m. (75th meridian time) and at noon (local mean solar time).

Table 2 contains the average amounts of radiation received daily on a horizontal surface from both sun and sky during each week, their departures from normal and the accumulated departures since the beginning of the year. The values at most of the stations are obtained from the records of the Eppley pyrheliometer recording on either a microammeter or a potentiometer.

Direct radiation intensities averaged above normal for November at Washington, Madison and Lincoln, and below normal at Blue Hill.

Total solar and sky radiation was above normal at all stations for which normals have been computed with the exception of Fairbanks, Twin Falls, Blue Hill, and Friday Harbor.

Polarization measurements made on 2 days at Madison give a mean of 64 percent with a maximum of 65 percent on the 14th. Both of these values are close to the corresponding normals for the month.

TABLE 1.—Solar radiation intensities during November 1938

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.													
Date	Sun's zenith distance										Noon Local mean solar time		
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°			
	75th mer. time	Air mass											
		A. M.						P. M.					
		e	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0		5.0	e
Nov. 1	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.		
Nov. 2	5.36	0.68	0.80	0.93	1.08	—	0.92	0.66	—	—	7.04		
Nov. 9	5.79	.65	.72	.87	1.11	—	—	—	—	—	6.02		
Nov. 10	3.15	.84	.93	1.11	1.34	—	1.22	—	—	—	3.45		
Nov. 14	4.37	.85	.92	1.03	1.18	—	1.97	.81	—	—	4.37		
Nov. 15	3.45	—	1.20	1.34	1.40	—	1.28	—	—	—	1.88		
Nov. 21	4.37	—	—	—	1.20	—	1.13	—	—	—	3.63		
Nov. 23	4.75	.76	.89	1.09	1.20	—	—	—	—	—	4.95		
Nov. 29	7.29	—	—	—	1.33	—	—	—	—	—	9.47		
Nov. 30	2.26	.86	1.00	1.06	1.27	—	1.10	—	—	—	3.30		
Nov. 30	3.63	.63	.69	1.10	—	—	—	.86	—	—	4.17		
Means	—	.75	.89	1.07	1.23	—	1.10	.86	—	—	—		
Departures	—	-.01	+.02	+.06	+.04	—	-.08	-.14	—	—	—		

MADISON, WIS.												
Nov. 11	4.57	—	—	—	1.13	—	—	—	—	—	—	5.16
Nov. 14	1.78	—	—	—	1.45	—	—	—	—	—	—	1.37
Nov. 22	2.16	—	—	—	1.50	—	—	—	—	—	—	1.60
Means	—	—	—	—	(1.39)	1.37	—	—	—	—	—	—
Departures	—	—	—	—	+.06	+.13	—	—	—	—	—	—

LINCOLN, NEBR.												
Nov. 4	5.36	—	—	—	—	—	1.19	1.11	0.99	—	—	5.16
Nov. 7	2.49	—	—	—	—	—	1.23	.99	—	—	—	2.26
Nov. 8	2.74	0.98	1.06	1.25	1.43	—	1.39	1.24	1.11	—	—	3.45
Nov. 9	4.37	1.08	1.18	1.32	1.47	—	—	—	—	—	—	3.99
Nov. 10	4.17	.97	1.10	1.24	1.42	—	1.22	1.05	.91	—	—	4.17
Nov. 14	2.74	—	1.02	1.15	1.39	—	1.21	1.08	.91	—	—	2.87
Nov. 15	2.74	.97	1.09	1.23	1.44	—	—	—	—	—	—	3.45
Nov. 18	3.45	1.10	1.21	1.34	1.52	—	1.33	1.18	1.08	—	—	3.30
Nov. 19	2.57	.83	1.01	1.26	1.44	—	—	—	—	—	—	4.17
Nov. 21	4.17	—	—	—	—	—	1.00	.83	.70	—	—	2.26
Nov. 23	1.52	—	—	—	—	—	1.27	1.13	.99	—	—	1.60
Nov. 25	2.87	—	—	—	1.27	—	—	—	—	—	—	2.26
Nov. 28	2.62	.68	.90	1.16	1.38	—	1.22	1.17	1.05	—	—	3.00
Nov. 29	2.06	.94	1.10	1.23	—	—	1.21	1.03	.83	—	—	3.00
Nov. 30	2.16	—	—	—	—	—	—	1.01	—	—	—	3.81
Means	—	.94	1.07	1.24	1.44	—	(1.39)	1.21	1.06	.93	—	—
Departures	—	+.02	+.04	+.06	+.08	—	+.04	+.02	+.01	.00	—	—

BLUE HILL, MASS.												
Nov. 1	3.8	—	1.07	1.25	1.39	—	1.26	1.16	1.07	—	—	4.2
Nov. 2	3.8	—	—	—	.92	—	.92	.64	.57	0.47	—	5.8
Nov. 4	7.1	—	—	—	1.22	—	1.24	—	—	—	—	8.8
Nov. 5	11.1	—	.86	1.05	1.35	—	—	—	—	—	—	11.1
Nov. 9	4.6	0.97	1.07	1.16	1.31	—	—	—	—	—	—	3.8
Nov. 10	3.5	1.01	1.13	1.28	1.38	—	—	—	—	—	—	4.8
Nov. 14	4.2	—	—	1.02	1.19	—	—	—	—	—	—	3.5
Nov. 15	2.2	—	—	1.32	1.36	—	—	—	—	—	—	2.1
Nov. 16	3.2	—	—	1.13	1.38	—	—	—	—	—	—	2.6
Nov. 21	4.0	—	—	—	1.32	—	—	—	—	—	—	3.6
Nov. 23	1.8	—	—	—	1.03	—	—	—	—	—	—	2.9
Means	—	.99	1.03	1.18	1.26	—	1.14	.90	.82	.47	—	—
Departures	—	-.06	+.03	-.02	+.02	—	-.12	-.23	-.17	-.37	—	—

\*Extrapolated.

TABLE 2.—Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface

Week beginning—	Gram-calories per square centimeter															
	Wash- ington	Madison	Lincoln	Chicago	New York	Fresno	Fair- banks	Twin Falls	La Jolla	New Orleans	River- side	Blue Hill	San Juan	Friday Harbor	Ithaca	New- port
Oct. 29.....	cal. 236	cal. 191	cal. 209	cal. 200	cal. 185	cal. 204	cal. 25	cal. 148	cal. 342	cal. 390	cal. 279	cal. 170	cal. 472	cal. 63	cal. 174	cal. 216
Nov. 5.....	214	184	244	172	201	298	36	192	338	384	317	216	338	119	186	271
Nov. 12.....	214	198	253	172	146	295	21	170	331	224	317	162	431	92	107	198
Nov. 19.....	165	170	256	153	114	266	13	189	314	340	275	118	468	143	102	158
Nov. 26.....	195	117	220	128	176	203	14	140	291	-----	264	182	506	79	65	216
Departures of daily totals from normals																
Oct. 29.....	-11	+5	-29	+43	+4	-48	-13	-72	+22	+95	-21	-53	+27	-63	+23	-----
Nov. 5.....	-11	+16	-2	+49	+18	+48	+4	-16	+10	+93	+8	+13	-89	+3	+50	-----
Nov. 12.....	+19	+53	+45	+66	+18	+48	-7	+7	+35	-12	+21	+11	-6	0	-6	-----
Nov. 19.....	-23	+38	+48	+41	-13	+30	-6	+34	+35	+96	+4	-34	+24	+39	0	-----
Nov. 26.....	+30	-9	+32	+35	+62	-19	+1	-15	+26	-----	+5	+27	+70	-15	-29	-----
Accumulated departures since Jan. 1																
	-11,235	-588	+2,310	+11,494	+5,110	-2,828	+4,697	-9,163	-1,232	+9,548	-5,880	-2,835	+13,174	+6,832	+7,736	-----

## POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.), Superintendent, U. S. Naval Observatory. Data furnished by the U. S. Naval Observatory in cooperation with Harvard and Mount Wilson Observatories. The difference in longitude is measured from the central meridian, positive west. The north latitude is positive. Areas are corrected for foreshortening and are expressed in millionths of the sun's visible hemisphere. The total area for each day includes spots and groups.]

Date	East- ern stand- ard time	Mt. Wilson group No.	Heliographic			Area		Spot count	Observatory
			Diff. in longi- tude	Longi- tude	Lat- tude	Spot or group	Total for each day		
1938 Nov. 1.....	A m 11 9	6181	-53.0	339.1	-4.0	36	-----	3	U. S. Naval.
		6177	-42.5	349.6	+11.0	194	-----	10	
		6176	-34.5	357.6	-9.0	218	-----	5	
		6175	-25.0	7.1	+17.0	73	-----	6	
		6180	-24.0	8.1	+8.5	36	-----	5	
		6182	-12.0	20.1	-14.0	73	-----	11	
		6168	+2.5	34.6	+24.0	291	-----	36	
		6164	+12.5	44.6	+13.0	121	-----	1	
		6184	+48.0	80.1	+24.0	24	-----	4	
		6173	+51.0	83.1	+13.0	12	-----	4	
		6163	+75.0	107.1	-23.0	194	-----	8	
		6160	+84.0	116.1	-14.0	291	1,563	6	
Nov. 2.....	11 6	6187	-68.0	310.9	+16.0	48	-----	2	Do.
		6186	-61.0	317.9	-31.5	12	-----	1	
		6181	-38.0	340.9	-5.0	36	-----	7	
		6177	-30.0	348.9	+11.0	145	-----	9	
		6176	-21.0	357.9	-9.0	145	-----	5	
		6175	-11.0	7.9	+16.0	48	-----	5	
		6180	-9.5	0.4	+8.0	145	-----	16	
		6182	+3.0	21.9	-14.0	48	-----	7	
		6168	+14.5	33.4	+24.0	194	-----	18	
		6164	+26.0	44.9	+14.0	73	-----	1	
		6184	+63.0	81.9	+24.0	24	-----	3	
		6173	+65.0	83.9	+14.0	145	1,063	20	
Nov. 3.....	11 12	6187	-55.0	310.7	+16.0	73	-----	4	Do.
		6186	-48.0	317.7	-31.0	6	-----	1	
		6181	-24.5	341.2	-5.0	24	-----	4	
		6177	-17.0	348.7	+11.0	145	-----	15	
		6176	-7.0	358.7	-9.0	97	-----	1	
		6185	-3.0	2.7	+9.5	12	-----	2	
		6175	+2.0	7.7	+15.5	36	-----	2	
		6180	+3.5	9.2	+8.0	291	-----	20	
		6182	+16.5	22.2	-14.5	24	-----	5	
		6188	+25.0	30.7	+13.0	6	-----	2	
		6168	+27.0	32.7	+25.0	194	-----	20	
		6164	+39.0	44.7	+14.0	73	-----	2	
		6173	+79.0	84.7	+14.0	97	1,078	9	
Nov. 4.....	13 9	6192	-84.0	267.4	-10.0	776	-----	8	Do.
		6189	-67.0	284.4	+10.5	24	-----	2	
		6191	-50.0	301.4	+15.0	12	-----	4	
		6187	-39.5	311.9	+16.0	73	-----	6	
		6181	-13.0	338.4	-5.0	12	-----	3	
		6181	-5.0	346.4	-6.0	12	-----	3	
		6177	-2.0	349.4	+11.0	121	-----	13	
		(*)	+1.0	352.4	-11.0	24	-----	5	
		6176	+8.0	359.4	-9.0	97	-----	1	
		6175	+16.5	7.9	+15.0	24	-----	2	
		6180	+19.0	10.4	+9.0	291	-----	15	
		6182	+31.0	22.4	-15.0	36	-----	5	
		6188	+40.0	31.4	+14.0	12	-----	3	
		6168	+41.0	32.4	+25.0	24	-----	6	
		6164	+53.0	44.4	+14.0	61	1,599	2	

## POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	East- ern stand- ard time	Mt. Wilson group No.	Heliographic			Area		Spot count	Observatory
			Diff. in longi- tude	Longi- tude	Lat- tude	Spot or group	Total for each day		
1938 Nov. 5.....	A m 12 26	6194	-85.0	253.6	-19.0	194	-----	3	U. S. Naval.
		6192	-68.0	270.6	-10.0	1,939	-----	30	
		6193	-30.0	308.6	+10.0	36	-----	8	
		6187	-26.0	312.6	+17.0	48	-----	1	
		6177	+7.5	346.1	+10.0	24	-----	5	
		6177	+15.0	353.6	+12.5	36	-----	2	
		6176	+21.5	0.1	-9.0	121	-----	2	
		6175	+30.0	8.6	+16.0	24	-----	4	
		6180	+32.0	10.6	+9.0	291	-----	13	
		6182	+43.0	21.6	-15.0	36	-----	5	
		6168	+54.0	32.6	+25.0	12	-----	5	
		6164	+66.0	44.6	+13.5	73	2,834	2	
Nov. 6.....	10 59	6194	-79.0	247.2	-20.0	48	-----	3	Mount Wil- son.
		6194	-70.0	256.2	-18.0	194	-----	6	
		6192	-56.0	270.2	-9.0	2,424	-----	75	
		6191	-27.0	299.2	+18.0	24	-----	2	
		6193	-16.0	310.2	+11.0	36	-----	3	
		6187	-13.0	313.2	+17.0	48	-----	2	
		6186	-13.0	313.2	-31.0	12	-----	3	
		6196	-8.5	317.7	+10.0	36	-----	5	
		6195	+7.0	333.2	+15.0	170	-----	20	
		6177	+20.0	346.2	+11.0	48	-----	10	
		6177	+29.0	355.2	+12.0	24	-----	4	
		6176	+36.0	2.2	-8.0	85	-----	4	
		6180	+45.0	11.2	+8.0	291	-----	9	
		6182	+55.0	21.2	-15.0	61	-----	2	
		6164	+79.0	45.2	+13.0	36	3,537	2	
Nov. 7.....	11 6	6198	-77.0	236.0	-18.0	388	-----	15	U. S. Naval.
		6194	-64.0	249.0	-20.0	61	-----	11	
		6194	-58.0	255.0	-18.0	279	-----	8	
		6192	-44.0	269.0	-9.0	2,424	-----	110	
		6187	-1.5	311.5	+17.0	48	-----	11	
		6196	-0.5	312.5	-31.0	6	-----	2	
		6196	+3.0	316.0	+9.5	48	-----	15	
		6195	+19.5	332.5	+15.5	339	-----	35	
		6177	+33.0	346.0	+11.0	12	-----	8	
		6177	+40.5	353.5	+13.0	6	-----	2	
		6176	+48.5	1.5	-7.0	61	-----	1	
		6180	+59.0	12.0	+9.0	291	-----	7	
		6182	+70.0	23.0	-15.0	145	4,108	9	
Nov. 8.....	10 52	6198	-63.0	236.9	-19.0	533	-----	16	Do.
		6194	-50.0	249.9	-19.5	48	-----	2	
		6194	-45.5	254.4	-18.0	291	-----	10	
		6192	-30.0	269.9	-9.0	2,327	-----	125	
		6197	-2.0	297.9	+23.0	6	-----	2	
		6191	-1.0	298.9	+11.0	6	-----	1	
		6187	+13.0	312.9	+17.0	48	-----	9	
		6196	+17.0	316.9	+9.5	48	-----	8	
		6195	+33.0	333.9	+15.0	339	-----	13	
		6177	+54.5	354.4	+15.0	6	-----	1	
		6176	+61.0	0.9	-9.0	61	-----	2	
		6180	+71.0	10.9	+8.0	297	3,980	4	
Nov. 9.....	11 5	6198	-48.0	238.6	-19.0	388	-----	10	Do.
		6194	-30.0	256.6	-18.0	242	-----	8	
		6192	-16.0	270.6	-9.0	2,133	-----	75	
		6187	+27.0	313.6	+17.0	36	-----	3	
		6196	+29.5	316.1	+10.0	48	-----	9	
		6195	+47.0	333.6	+15.0	339	-----	12	
		6176	+76.0	2.6	-7.5	61	-----	1	
		6180	+87.0	12.6	+8.0	97	3,344	1	

## POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	East- ern stand- ard time	Mt. Wilson group No.	Heliographic			Area		Spot count	Observatory
			Diff. in longi- tude	Longi- tude	Lat- tude	Spot or group	Total for each day		
1938 Nov. 10...	11 14	6198	-35.0	238.4	-19.0	388	-----	38	U. S. Naval.
		6194	-18.0	255.4	-18.5	206	-----	4	
		6192	-2.5	279.9	-9.0	2,133	-----	125	
		6197	+26.0	299.4	+20.0	6	-----	1	
		6187	+40.0	313.4	+17.0	24	-----	1	
		6196	+45.0	318.4	+10.0	12	-----	1	
		6195	+61.0	334.4	+15.0	242	3,011	9	
Nov. 11...	10 58	6199	-66.0	194.3	-8.0	24	-----	3	Mount Wil- son.
		6198	-21.0	239.3	-19.0	291	-----	25	
		6194	-3.0	257.3	-17.0	218	-----	30	
		6192	+11.0	271.3	-9.0	2,133	-----	165	
		6195	+72.0	332.3	+15.5	73	2,739	8	
Nov. 12...	11 31	6203	-80.0	166.8	+20.0	48	-----	2	U. S. Naval.
		6202	-78.0	168.8	-10.0	315	-----	4	
		6199	-51.5	195.3	-8.0	16	-----	6	
		6201	-50.5	196.3	+10.5	73	-----	8	
		6200	-41.0	205.8	-19.0	170	-----	14	
		6195	-7.0	239.8	-18.0	242	-----	30	
		6194	+9.5	256.3	-17.0	194	-----	2	
		6192	+25.0	271.8	-9.0	1,939	2,907	110	
Nov. 13...	11 16	6203	-68.0	165.5	+20.0	61	-----	9	Mount Wil- son.
		6202	-66.0	167.8	-10.0	315	-----	10	
		6199	-38.0	195.8	-8.0	12	-----	1	
		6201	-37.0	196.8	+10.5	145	-----	28	
		6200	-28.0	205.8	-19.0	194	-----	25	
		6204	0.0	233.8	-7.0	48	-----	7	
		6198	+7.0	240.8	-18.0	194	-----	22	
		6194	+22.0	255.8	-17.0	194	-----	6	
		6192	+38.0	271.8	-9.0	1,600	2,763	105	
Nov. 14...	10 57	6203	-65.0	155.8	+20.5	97	-----	6	U. S. Naval.
		6203	-56.0	164.8	+20.5	206	-----	4	
		6202	-51.0	169.8	-9.5	339	-----	8	
		6205	-27.0	193.8	+20.0	73	-----	7	
		6201	-25.0	195.8	+11.0	121	-----	11	
		6200	-14.0	206.8	-19.5	170	-----	11	
		6204	+17.0	237.8	-6.0	48	-----	6	
		6198	+19.5	240.3	-19.0	170	-----	11	
		6194	+35.0	255.8	-17.0	218	-----	3	
		6192	+50.0	270.8	-9.0	1,600	3,042	45	
Nov. 15...	11 9	6206	-76.0	131.5	+13.0	12	-----	2	Do.
		6203	-49.5	158.0	+20.0	36	-----	6	
		6203	-43.0	164.5	+19.5	194	-----	3	
		6202	-37.5	170.0	-9.5	291	-----	2	
		6201	-11.0	196.5	+11.0	97	-----	7	
		6205	-9.0	198.5	+18.0	73	-----	13	
		6200	+1.0	208.5	-19.0	201	-----	25	
		6204	+29.0	236.5	-7.0	388	-----	32	
		6198	+32.0	239.5	-18.0	85	-----	4	
		6194	+48.0	255.5	-18.0	170	-----	2	
		6192	+65.0	272.5	-9.0	1,309	2,946	22	
Nov. 16...	10 54	6206	-68.0	126.4	+14.0	24	-----	5	Do.
		6207	-35.0	159.4	+6.0	24	-----	1	
		6203	-33.0	161.4	+20.0	242	-----	10	
		6202	-25.0	169.4	-10.0	291	-----	2	
		6201	+2.0	196.4	+10.5	73	-----	5	
		6205	+3.0	197.4	+19.0	73	-----	10	
		6200	+14.0	208.4	-19.5	388	-----	37	
		6204	+43.0	237.4	-6.0	630	-----	24	
		6198	+44.0	238.4	-19.0	73	-----	3	
		6194	+61.0	255.4	-18.0	121	-----	1	
		6192	+79.0	273.4	-10.0	1,309	3,248	13	
Nov. 17...	11 8	6206	-55.0	126.1	+15.0	48	-----	11	Do.
		6203	-27.0	154.1	+23.0	36	-----	2	
		6207	-22.0	159.1	+7.0	73	-----	12	
		6203	-20.0	161.1	+20.0	218	-----	12	
		6202	-10.0	171.1	-9.5	291	-----	3	
		6201	+16.0	197.1	+10.5	73	-----	1	
		6205	+20.0	201.1	+19.0	24	-----	2	
		6200	+28.0	209.1	-19.0	582	-----	40	
		6204	+56.0	237.1	-8.0	824	-----	33	
		6198	+57.5	238.6	-19.0	36	-----	4	
		6194	+74.0	255.1	-18.0	97	2,302	1	
Nov. 18...	12 0	6206	-41.0	126.5	+14.0	24	-----	4	Do.
		6203	-12.0	155.5	+23.0	12	-----	2	
		6207	-6.0	161.5	+7.0	48	-----	5	
		6203	-4.0	163.5	+19.5	194	-----	3	
		6202	+2.0	169.5	-10.0	291	-----	6	
		6201	+29.0	196.5	+10.0	48	-----	1	
		6205	+34.5	202.0	+18.0	24	-----	4	
		6200	+41.0	208.8	-19.0	727	-----	45	
		6204	+70.0	237.5	-9.0	873	-----	22	
		6198	+79.0	246.5	-19.0	12	2,253	1	

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## POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	East- ern stand- ard time	Mt. Wilson group No.	Heliographic			Area		Spot count	Observatory
			Diff. in longi- tude	Longi- tude	Lat- tude	Spot or group	Total for each day		
1938 Nov. 19...	h m 11 30	6206	-25.0	129.6	+17.0	24	-----	3	Mount Wil- son.
		6203	+1.0	155.6	+20.0	194	-----	10	
		6207	+7.0	161.6	+6.5	145	-----	35	
		6208	+13.0	167.6	+25.0	12	-----	2	
		6202	+16.0	170.6	-10.0	315	-----	1	
		6201	+41.0	195.6	+10.0	24	-----	5	
		6205	+45.0	199.6	+18.0	12	-----	3	
		6200	+55.0	209.6	-19.0	1,600	-----	100	
		6204	+84.0	238.6	-8.0	582	2,908	8	
Nov. 20...	13 17	6211	-56.0	84.4	+1.5	6	-----	1	U. S. Naval.
		6207	+21.0	161.4	+6.0	121	-----	14	
		6203	+24.0	164.4	+19.0	194	-----	2	
		6202	+30.0	170.4	-10.5	291	-----	2	
		6201	+57.0	197.4	+11.0	12	-----	1	
		6200	+68.0	208.4	-19.0	1,600	2,224	35	
Nov. 21...	11 25	6210	+9.5	137.8	-25.0	36	-----	3	Do.
		6209	+15.0	143.3	+21.0	24	-----	4	
		6207	+34.0	162.3	+6.0	194	-----	18	
		6203	+37.0	165.3	+19.5	170	-----	10	
		6206	+39.0	167.3	+25.0	48	-----	6	
		6202	+43.0	171.3	-10.5	291	-----	9	
		6200	+78.0	201.3	-20.0	1,212	1,975	40	
Nov. 22...	11 18	6212	-48.0	67.1	+17.0	12	-----	6	Do.
		6210	+25.0	140.1	-23.0	12	-----	4	
		6209	+27.0	142.1	+22.0	24	-----	6	
		6207	+46.0	161.1	+6.0	194	-----	22	
		6203	+49.0	164.1	+19.0	97	-----	11	
		6202	+55.0	170.1	-10.0	242	-----	2	
		6208	+55.0	170.1	+25.0	36	817	4	
Nov. 23...	11 14	6213	-70.0	32.0	+15.0	194	-----	18	Do.
		6210	+40.0	142.0	-23.5	6	-----	1	
		6209	+41.0	143.0	+21.0	12	-----	3	
		6207	+60.0	162.0	+6.0	194	-----	16	
		6203	+63.0	165.0	+19.5	73	-----	5	
		6202	+68.0	170.0	-10.0	242	-----	1	
		6208	+68.0	170.0	+25.0	97	818	6	
Nov. 24...	10 57	6214	-57.5	31.5	-18.0	24	-----	2	Mount Wil- son.
		6213	-54.5	34.5	+15.0	970	-----	45	
		6212	-20.0	69.0	+18.0	61	-----	9	
		6215	-3.0	86.0	+14.0	36	-----	7	
		(*)	+11.5	100.5	-14.0	12	-----	3	
		(*)	+12.0	101.0	-24.0	12	-----	5	
		6207	+73.0	162.0	+7.0	121	-----	15	
		6208	+0.0	169.0	+24.0	97	-----	6	
		6202	+82.0	171.0	-10.0	194	-----	3	
		6203	+85.0	174.0	+19.0	48	1,575	3	
Nov. 25...	11 1	6214	-43.0	32.8	-18.0	36	-----	10	U. S. Naval.
		6213	-41.0	34.8	+14.0	1,164	-----	75	
		6212	-7.0	68.8	+17.5	170	-----	28	
		6217	+3.0	78.8	+18.0	6	-----	8	
		6215	+10.0	85.8	+13.0	48	-----	2	
		6216	+27.0	102.8	-18.0	24	-----	6	
		6209	+65.0	140.8	+24.0	24	-----	2	
		6207	+85.0	160.8	+7.0	145	1,617	5	
Nov. 26...	10 51	6214	-30.0	32.7	-18.0	73	-----	11	Do.
		6213	-27.0	35.7	+14.0	1,097	-----	78	
		6212	+6.0	68.7	+17.0	97	-----	24	
		6217	+17.0	79.7	+17.5	6	-----	1	
		6216	+41.0	103.7	-17.0	36	1,909	4	
Nov. 27...	11 43	6218	-70.0	339.0	-11.0	24	-----	1	Do.
		6214	-16.0	33.0	-18.0	194	-----	32	
		6213	-14.0	35.0	+14.0	1,745	-----	95	
		6212	+17.0	66.0	+17.0	97	-----	9	
		6212	+23.5	72.5	+17.0	6	-----	1	
		6216	+51.0	100.0	-17.0	12	2,078	2	
Nov. 28...	11 0	6219	-77.0	319.2	+12.0	48	-----	2	Do.
		6218	-58.0	338.2	-11.5	24	-----	4	
		6214	-3.0	33.2	-18.0	339	-----	88	
		6213	-1.0	35.2	+14.0	2,133	-----	120	
		6212	+29.0	65.2	+16.0	61	-----	6	
		6212	+35.0	71.2	+16.0	6	2,611	1	
Nov. 29...	10 51	6219	-62.0	321.1	+11.5	61	-----	2	Do.
		6214	+10.0	33.1	-18.0	455	-----	34	
		6213	+12.0	35.1	+14.0	1,891	-----	70	
		6212	+41.5	64.6	+16.0	24	2,461	5	
Nov. 30...	10 52	6219	-49.0	320.9	+11.0	61	-----	1	Do.
		6214	+24.0	33.9	-18.0	485	-----	25	
		6213	+25.0	34.9	+14.0	1,697	-----	42	
		6212	+54.0	63.9	+16.0	12	2,255	2	

### PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR NOVEMBER 1938

(Dependent alone on observations at Zurich and its station at Arosa)

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

November 1938	Relative Numbers	November 1938	Relative Numbers	November 1938	Relative Numbers
1	a 146	11	a 125	21	78
2		12	EEcccd 134	22	56
3	a 162	13	Macd 152	23	d 61
4	aad 128	14	152	24	Mc 79
5	112	15	a 161	25	Ec 94
6	Mcd 167	16	Eac 157	26	a 85
7	d 176	17		27	110
8	159	18	aa 115	28	ab 107
9	138	19	a 106	29	
10	b 131	20	97	30	95

Mean: 27 days=121.6

Nov. 10. Middle large, bright chromospheric eruption	a m a m 13 35-13 50, M.
13. Middle large, bright chromospheric eruption	13 38-14 40, W.
20. Middle large, bright chromospheric eruption	13 45-14 00, W.
25. Middle large, bright chromospheric eruption	8 50- 9 00, & 13 55-14 50, E.
27. Middle large, bright chromospheric eruption	9 40-10 05.
28. Middle large, bright chromospheric eruption	13 30-14 30.

a= Passage of an average-sized group through the central meridian.

b= Passage of a large group or spot through the central meridian.

c= New formation of a group developing into a middle-sized or large center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central circle zone.

d= Entrance of a large or average-sized center of activity on the east limb.

### AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE in charge]

By B. FRANCIS DASHIELL

During November 1938 a total of 474 airplane and radiosonde observations were made in the United States, and the mean free-air data based on these observations, shown in tables 1 and 1a, includes pressure, temperature, and relative humidity recorded at certain geometric heights. Of all radiosonde ascensions launched at stations making such observations, about 30 percent reached a height of 19 kilometers.

The "means" are omitted from the tables whenever less than 15 observations are made at the surface and less than 5 at a standard height, but 15 observations are required for those levels which fall within the limits of the monthly vertical range of the tropopause. A description of the methods used for computing these means will be found in the January 1938 MONTHLY WEATHER REVIEW.

Chart I, published elsewhere in this REVIEW, shows the departures of the mean surface temperature ( $^{\circ}$  F.) from normal. The month of November was warm over the entire country east of the Mississippi River valley. In that area positive departures ranged from  $2^{\circ}$  F. to  $6^{\circ}$  F. over the Great Lakes region and the Middle Atlantic coast. The weather was cool over the western half of the United States, except along the southern California coast. There the mean temperature remained close to normal. Subnormal temperatures with deficiencies ranging from  $3^{\circ}$  F. to  $6^{\circ}$  F. occurred over portions of the central Rocky Mountain States.

Mean free-air temperatures ( $^{\circ}$  C.) above the surface (tables 1 and 1a) were rather evenly distributed in all levels below 5 kilometers. During November, however, the coldest weather was centered over the north-central States. In this area, upward from 0.5 to 11 kilometers, Fargo, N. Dak., reported the lowest temperatures recorded at each level. However, radiosonde observations made farther south, at Omaha, Nebr., and Oklahoma City, Okla., above 11 kilometers, indicated decidedly lower temperatures than those reported at Fargo, N. Dak. This fact was particularly noticeable at 17 kilometers, where the mean temperature was  $13.0^{\circ}$  C. lower over Oklahoma City, Okla., than that which was recorded over Fargo, N. Dak.

The lowest mean free-air temperature recorded in the high altitudes by means of radiosonde was  $-72.2^{\circ}$  C. over Washington, D. C., at 17 kilometers. But, in the lower levels below 5 kilometers, where observations are made by both radiosonde and airplane, the lowest mean tempera-

tures for the country during the current month were recorded over Fargo, N. Dak. These temperatures, for each level from 0.5 to 5 kilometers, respectively, were  $-4.7^{\circ}$  C.,  $-5.3^{\circ}$  C.,  $-5.7^{\circ}$  C.,  $-6.9^{\circ}$  C.,  $-9.1^{\circ}$  C.,  $-11.7^{\circ}$  C.,  $-17.0^{\circ}$  C., and  $-22.8^{\circ}$  C. The highest mean temperatures recorded in each level for the month were:  $13.9^{\circ}$  C.,  $13.2^{\circ}$  C.,  $11.4^{\circ}$  C.,  $9.6^{\circ}$  C.,  $7.7^{\circ}$  C., and  $5.5^{\circ}$  C., over San Diego, Calif., and  $0.1^{\circ}$  C., and  $-5.7^{\circ}$  C., over Pensacola, Fla.; all recorded at 0.5, 1, 1.5, 2, 2.5, 3, 4, and 5 kilometers, respectively. Below-zero mean temperatures were reported from all stations at 5 kilometers and higher, and at Fargo, N. Dak., and Sault Ste. Marie, Mich., at all levels beginning with that at 0.5 kilometer.

During November the mean temperatures observed at all stations were lower than in the preceding month of October. Such seasonal changes were decidedly outstanding at Fargo, N. Dak., Sault Ste. Marie, Mich., Salt Lake City, Utah, Billings, Mont., Omaha, Nebr., and Oklahoma City, Okla. But, on the other hand, at Lakehurst, N. J., San Diego, Calif., Norfolk, Va., and Oakland, Calif., the November mean temperatures were very little lower than in October. At Fargo, N. Dak., the mean temperatures for November were lower than in October by  $15.1^{\circ}$  C.,  $15.8^{\circ}$  C.,  $14.5^{\circ}$  C.,  $13.9^{\circ}$  C.,  $13.7^{\circ}$  C.,  $13.4^{\circ}$  C.,  $12.4^{\circ}$  C., and  $11.4^{\circ}$  C.; but over San Diego, Calif., they differed only by  $1.3^{\circ}$  C.,  $2.1^{\circ}$  C.,  $2.7^{\circ}$  C.,  $1.1^{\circ}$  C.,  $1.3^{\circ}$  C.,  $0.0^{\circ}$  C.,  $0.2^{\circ}$  C., and  $1.0^{\circ}$  C.; at 0.5, 1, 1.5, 2, 2.5, 3, 4, and 5 kilometers, respectively.

The distribution of atmospheric pressure during the month of November was remarkably uniform. Isobaric charts, which were prepared from the mean pressure data given in tables 1 and 1a, showed that a well-defined area of low pressure existed over the north-central States at all levels up to 5 kilometers. Its statistical center was over Fargo, N. Dak., reaching as high as 16 kilometers. Above this altitude the center spread out to include Sault Ste. Marie, Mich., and Omaha, Nebr. Higher pressures prevailed over the South, and particularly so at Pensacola, Fla., up to 5 kilometers. Then, above that level, the highest pressures were found over Nashville, Tenn., where radiosonde observations are made. They continued upward to the maximum altitude reached during the month—20 kilometers.

The differences in pressure existing between the centers of low and high pressure at each level over Fargo, N. Dak.,

and Pensacola, Fla., respectively, were found to increase steadily with altitude. They were: 8, 12, 15, 17, 18, 20, 21, and 25 millibars, at 0.5, 1, 1.5, 2, 2.5, 3, 4, and 5 kilometers, respectively. Mean free-air pressures along the Atlantic and Pacific coasts were nearly the same at each level, being only slightly lower than the pressures over Pensacola. The November mean pressures in the low area over Fargo, N. Dak., and Sault Ste. Marie, Mich., were considerably less than those recorded in the preceding month of October. But over the southern States only a slight negative difference was noted in the higher pressures that were recorded.

High percentages of mean relative humidity were found also over Fargo, N. Dak., where the lowest temperatures and lowest pressures in the country were centered during November. These humidities varied from 85 percent at 0.5 kilometer, to 63 percent at 5 kilometers. Humidity also was relatively high over the northern Rocky Mountain region. The driest air of the month occurred over El Paso, Tex., upward to 3 kilometers, and then over Pensacola, Fla., up to 5 kilometers, inclusive, where it was only 20 percent. In the lower levels the humidity ranged higher along the Atlantic coast than on the Pacific, but above 2.5 kilometers the Pacific coast humidity became slightly higher. The mean relative humidity recorded at all levels, like the temperature and pressure, was more evenly distributed in November than during the preceding month of October, or in the previous months of spring and summer. During November the humidity over the portion of the country along the Gulf and southern border was lower than in the preceding month, but elsewhere the differences were not so pronounced.

Resultant winds in the free atmosphere, based on pilot-balloon observations made near 5 a. m. (75th meridian time), are shown in table 2. The distribution or flow of upper-air winds during the current month of November was more stream-lined than in October. Except for several stations that showed outstanding tendencies, the resultant wind directions for November were generally quite normal. In each level the wind directions that departed widely from normal were indicated by their November results of: 179° at Atlanta, Ga.; 179°, 220°, and 234° at Pensacola, Fla.; 283° at Salt Lake City, Utah; 67° at Key West, Fla.; 343° at Medford, Oreg.; and 332° at Salt Lake City, Utah; as compared to their normals of 326°, 341°, 311°, 310°, 191°, 5°, 307°, and 301°; at 0.5, 1, 1.5, 2, 2.5, 3, 4, and 5 kilometers, respectively.

In each level there were resultant wind directions that actually became normal or very nearly so. The stations reporting these conditions, with the amount of departure given in degrees, are: Oakland, Calif., (2°) with the current direction rotated counterclockwise away from its normal, at 0.5 kilometer; Fargo, N. Dak., (0°) at 1, 1.5, and 2 kilometers; Washington, D. C., (3°) rotated counterclockwise, at 2.5 kilometers; and Albuquerque, N. Mex., (0°) at 3, 4, and 5 kilometers, inclusive.

Wind directions in the Southeast, especially over Pensacola, Fla., showed the largest departures from normal for the month. The differences (in degrees) between these directions and their normals were: 36° (when rotated clockwise from normal); 162°, 91°, 76°, 38°, and 48° (all rotated counterclockwise); at 0.5, 1, 1.5, 2, 2.5, and 3 kilometers, respectively. Resultant directions at Atlanta, Ga., also showed marked departures. The differences were: 147°, 47°, 33°, 30°, 22°, 15°, and 24° (all rotated counterclockwise); at 0.5, 1, 1.5, 2, 2.5, 3, and 4 kilometers, respectively. At Key West, Fla., too, departures from normal were large. But, at all levels above 0.5 kilometer,

the departures were in opposite directions to those noted at Atlanta, Ga., and Pensacola, Fla.

The differences at Key West, Fla., were: 13°, 17°, 45°, 69°, 63°, and 27° (with the current direction being rotated clockwise from normal), at all levels from 1 to 4 kilometers, inclusive. At Sault Ste. Marie, Mich., the current wind direction departures were all counterclockwise, and they differed from their normals by as much as 50°, 40°, 24°, 39°, 45°, and 44°, at the surface, and 0.5, 1, 1.5, 2, and 2.5 kilometers, respectively. But at Albuquerque, N. Mex., Billings, Mont., Boston, Mass., Oklahoma City, Okla., Seattle, Wash., Chicago, Ill., Brooklyn, N. Y., Fargo, N. Dak., Omaha, Nebr., and St. Louis, Mo., in the order given, the resultant wind directions showed slight and unimportant departures from normal at all levels.

It is interesting to note that practically all departures of resultant wind directions from normal in the upper air showed tendencies to turn somewhat south of normal, with the monthly resultant being rotated away from normal in a counterclockwise direction. These conditions were noted at the surface and all levels over Brooklyn, N. Y., Boston, Mass., Cincinnati, Ohio, St. Louis, Mo., Chicago, Ill., Nashville, Tenn., Detroit, Mich., Sault Ste. Marie, Mich., and Albuquerque, N. Mex. Some stations showed similar departures in the free-air but not at the surface (where clockwise departures prevailed).

Stations showing the latter tendencies were: Washington, D. C., Pensacola, Fla., Fargo, N. Dak., Omaha, Nebr., Atlanta, Ga., and Oklahoma City, Okla. Key West, Fla., was the only station reporting clockwise departures at all levels, as mentioned above, while Salt Lake City, Utah, and Oakland, Calif., Medford, Oreg., Seattle, Wash., and Spokane, Wash. (all Pacific coast points) had similar departures in the higher levels only. Of these coastal stations, the latter three show decidedly southerly resultant wind directions, both normally and for the current month, while those at Oakland and San Diego, Calif.—farther south along the coast—had normal and current directions that are nearly north.

The distribution of resultant wind directions over the United States at all upper-air levels during November showed that westerly winds predominated. At 0.5 kilometer 69 percent of all the winds had westerly components, and this increased steadily to 96 percent at 2.5 kilometers and 100 percent at 4 and 5 kilometers. Of all the westerly winds the larger percentage in the lower levels had southwesterly components. This ranged from 75 percent at 1.5 kilometers to 11 percent at 4 kilometers. Practically all of the winds with easterly components fell within the southeast quadrant. The large percentage of winds having southwesterly directions accounts for the large number of departures from normal that were south of, or in a counterclockwise rotation from, normal. The average departure in each level above the surface, for all stations, was about 20°, and 69 percent of these were counterclockwise, or generally south of normal.

Resultant wind velocities for November showed rather light departures from normal velocities at nearly all stations. The largest departures from normal in each level occurred at Nashville, Tenn. (+1.3 and +3.2 m. p. s.); Sault Ste. Marie, Mich. (+3.9, +4.3, +3.6, and +3.2); Cincinnati, Ohio (+3.5) and Pensacola, Fla. (-3.5); Atlanta, Ga. (-5.6); and Salt Lake City, Utah (+3.6); at the surface, and 0.5, 1, 1.5, 2, 2.5, 3, 4, and 5 kilometers, respectively.

At Sault Ste. Marie, Mich., the largest velocity departures were recorded. In the lower levels—1, 1.5, 2, and 2.5 kilometers—the resultant velocities showed positive

departures of from 3 to 4 meters per second. But, at Fargo, N. Dak., where large departures in wind direction were noted, the velocity variations from normal were slight—averaging only about 0.5 m. p. s. Spokane, Wash., and Medford, Oreg., also had very slight departures from normal velocities except at the 4-kilometer level. At Cheyenne, Wyo., however, the wind velocities were nearly normal at all levels and with no departures whatever at two of the levels. Greater-than-normal or positive velocity departures occurred at all levels over Billings, Mont., Chicago, Ill., Cincinnati, Ohio, Detroit, Mich., Key West, Fla., Nashville, Tenn., Sault Ste. Marie, Mich., and Oklahoma City, Okla., while negative departures were found only at Atlanta, Ga., and Washington, D. C.

Table 3 shows the maximum free-air velocities for different sections of the United States that occurred between the surface and 2.5 kilometers, 2.5 kilometers and 5 kilometers, and above 5 kilometers. A number of these high-altitude observations were made with the new 100-gram balloons. These have higher ascensional rates and reach greater elevations. The month of November 1938 was characterized by extremely high wind velocities in the upper air. At Winslow, Ariz., on the 14th, a velocity of 90 meters per second (202 miles per hour) from the WSW, was recorded at 12 kilometers. It appears that this is a record for the country, exceeding that of 81 m. p. s. estab-

lished at Lansing, Mich., at 6 kilometers, in December 1919. The Winslow observation was made with the 100-gram balloon at the end of 37 minutes by means of a single theodolite. But while this velocity is unusually high, it agrees closely with similar records obtained at surrounding stations on the same and adjoining dates.

Further high velocities above 5 kilometers were noted over Modena, Utah (66 m. p. s. at 17 kilometers), which exceeded the previous record of 58 m. p. s.; and over Fargo, N. Dak. (62 m. p. s. at 8.5 kilometers), which also surpassed the record established at that station. Maximum wind velocities also occurred at Medford, Oreg. (57.6 m. p. s. at 9.8 kilometers); Nashville, Tenn. (50 m. p. s. at 8.2 kilometers); Wichita, Kans. (57.6 m. p. s. at 9.5 kilometers); and Oklahoma City, Okla. (55 m. p. s. at 7.6 kilometers). These wind speeds also exceeded the previous all-time records.

In the levels below 5 kilometers extremely high wind velocities were the rule during November. Washington, D. C., recorded 69.1 meters per second (155 miles per hour) from the WNW on the 14th at only 2.6 kilometers above the surface. This surpassed a previous record of 41 m. p. s. made at 10 kilometers. High wind speeds, some of them record breaking, occurred in each section of the country at the lower levels, as shown in table 3, and ranged from 32 to 56 m. p. s. below 2.5 kilometers, and from 44 to 69 m. p. s. between 2.5 and 5 kilometers.

TABLE 1.—Mean free-air barometric pressures (*P*) in mb, temperatures (*T*) in °C., and relative humidities (*R. H.*) in percent obtained by air planes during November 1938

Stations and elevations in meters above sea level	Altitude (meters) m. s. l.																											
	Surface			500			1,000			1,500			2,000			2,500			3,000			4,000			5,000			
	No. of obs.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.	P	T	R. H.
Billings, Mont. (1090 m)	29	891	-0.4	67							847	+0.7	58	796	-1.9	58	747	-5.2	59	700	-8.6	60	615	-14.7	60	538	-21.5	60
Cheyenne, Wyo. (1573 m)	30	809	-2.4	62										796	-6	57	748	-2.3	54	702	-5.5	53	617	-11.5	52	541	-18.3	51
Chicago, Ill. (157 m)	29	994	3.4	74	956	4.6	68	900	3.6	64	846	1.5	62	794	-4	58	746	-2.7	56	701	-5.2	56	616	-11.3	58	540	-16.5	56
Coco Solo, C. Z. (15 m)	26	1009	24.5	93	954	23.0	87	902	20.3	86	850	17.8	81	802	15.7	77	756	13.3	75	712	10.8	72	631	8.2	71	558	-1.1	58
El Paso, Tex. (1193 m)	30	884	3.8	36							852	8.4	34	802	6.7	32	754	4.9	30	709	2.3	29	626	-2.7	25	551	-8.6	23
Lakehurst, N. J. (39 m)	24	1017	7.3	87	961	10.4	66	905	8.1	66	852	6.6	62	801	4.8	52	753	3.1	44	708	0.0	43	624	-6.0	41			
Norfolk, Va. (10 m)	18	1023	9.5	91	965	10.8	72	909	8.3	66	856	7.2	60	805	5.3	55	757	4.0	45	711	1.5	41	628	-4.0	36	552	-10.6	35
Pearl Harbor, T. H. (6 m)	30	1015	22.1	78	959	21.8	70	903	18.7	76	854	15.8	78	805	14.5	63	758	14.1	41	715	12.2	34	634	7.8	26	561	2.9	28
Pensacola, Fla. (13 m)	28	1021	11.6	86	962	13.2	71	907	11.6	66	855	10.2	58	805	8.7	51	757	7.3	38	712	5.4	30	628	.1	23	555	-5.7	20
St. Thomas, V. I. (8 m)	29	1014	26.7	78	958	23.4	86	905	20.3	87	854	17.7	80	805	14.9	77	756	12.6	69	715	10.4	61	634	5.4	49	590	1.1	41
Salt Lake City, Utah (1288 m)	30	876	-2.6	82							853	-6	66	801	-2.1	60	752	-4.7	59	705	-7.6	60	620	-11.7	54	543	-18.1	52
San Diego, Calif. (10 m)	30	1017	8.8	75	959	13.9	63	904	13.2	53	851	11.4	47	802	9.6	41	754	7.7	37	709	5.5	35	627	0.0	31	553	-6.6	29
Seattle, Wash. (10 m)	17	1022	6.1	80	963	6.5	70	906	5.0	64	852	2.9	61	801	.8	56	752	-1.8	54	706	-4.5	54	621	-10.9	55			
Spokane, Wash. (597 m)	30	950	-7	86				904	.2	75	849	-1.2	66	797	-3.8	64	748	-6.1	65	701	-8.7	64	616	-13.7	61	539	-19.3	

<sup>1</sup> Navy.

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

NOTE.—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

TABLE 1a.—Mean free-air barometric pressures (*P*) in mb, temperatures (*T*) in °C., and relative humidities (*R. H.*) in percent obtained by radiometeorographs during November 1938

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																											
	Fargo, N. Dak. (274 m)				Nashville, Tenn. (180 m)				Oakland, Calif. (2 m)				Oklahoma City, Okla. (391 m)				Omaha, Nebr. (300 m)				Sault Ste. Marie, Mich. (221 m)				Washington, D. C. (13 m)			
	Number of obs.	P	T	R H	Number of obs.	P	T	R H	Number of obs.	P	T	R H	Number of obs.	P	T	R H	Number of obs.	P	T	R H	Number of obs.	P	T	R H	Number of obs.	P	T	R H
Surface.....	30	982	-6.5	84	30	999	6.3	78	30	1,021	7.7	73	29	972	4.3	68	30	980	0.8	74	30	987	-0.1	87	29	1,022	6.1	83
500.....	30	954	-4.7	85	30	961	8.8	68	30	962	10.6	63	29	959	5.5	66	30	957	2.1	67	30	954	-1.2	88	29	962	6.8	71
1,000.....	30	895	-5.3	82	30	904	6.9	63	30	905	9.2	57	29	902	6.5	58	30	899	2.5	63	30	896	-1.1	85	29	905	5.5	68
1,500.....	30	840	-5.7	77	30	851	4.9	57	30	852	7.5	52	29	849	6.2	50	30	845	1.3	59	30	841	-2.8	79	29	851	4.0	67
2,000.....	30	788	-0.9	72	30	800	3.6	54	30	802	5.9	47	29	799	4.5	46	30	794	-1.5	55	30	789	-5.2	77	29	800	2.4	65
2,500.....	30	739	-9.1	69	30	752	2.1	53	30	754	3.8	45	29	751	2.7	43	30	745	-2.9	52	30	740	-7.6	75	29	751	0.9	58
3,000.....	30	692	-11.7	68	29	707	0.5	45	29	709	1.6	43	29	706	1.3	40	30	700	-5.5	52	30	694	-10.3	73	29	705	-9.9	53
4,000.....	30	607	-17.0	67	29	624	-3.9	35	29	625	-4.0	42	29	622	-5.0	37	28	615	-10.9	52	30	608	-15.4	68	29	622	-5.9	47
5,000.....	30	530	-22.8	63	29	549	-9.8	32	29	550	-9.7	41	27	548	-10.9	34	28	539	-15.5	49	30	532	-21.0	63	29	546	-11.8	43
6,000.....	30	462	-29.4	61	29	481	-15.9	32	29	482	-16.2	40	26	480	-17.3	33	26	471	-22.9	47	30	464	-27.0	59	28	478	-18.0	42
7,000.....	30	401	-35.8	59	29	421	-22.7	30	29	422	-23.2	39	26	420	-24.4	32	26	410	-29.8	40	30	403	-34.5	58	25	418	-24.6	42
8,000.....	29	346	-42.2	58	29	366	-29.8	29	29	367	-30.2	38	25	365	-31.2	32	25	358	-35.2	40	30	349	-39.8	58	24	364	-31.2	37
9,000.....	29	298	-48.0	58	29	317	-36.5	29	29	318	-37.8	38	25	317	-37.7	32	23	308	-42.9	40	29	301	-45.9	58	24	316	-35.0	37
10,000.....	29	256	-51.5	58	29	274	-42.9	29	29	275	-44.7	38	25	274	-44.5	32	23	265	-48.9	40	29	259	-50.3	58	23	272	-44.4	37
11,000.....	29	219	-53.1	58	29	236	-48.5	29	25	236	-50.6	40	25	235	-50.9	32	23	227	-53.1	40	29	222	-53.4	58	21	234	-49.5	37
12,000.....	28	188	-53.1	58	27	203	-52.2	29	25	202	-54.4	40	23	202	-54.8	32	23	193	-56.7	40	29	190	-54.6	58	17	200	-54.3	37
13,000.....	26	161	-53.6	58	25	173	-56.1	29	23	172	-56.7	40	23	172	-58.2	32	16	165	-57.7	40	27	162	-55.4	58	14	171	-58.5	37
14,000.....	24	137	-54.7	58	25	148	-58.8	29	19	147	-58.9	40	17	147	-61.8	32	15	140	-62.2	40	24	138	-60.6	58	12	145	-62.2	37
15,000.....	23	117	-55.9	58	23	126	-61.2	29	19	125	-60.8	40	14	125	-65.0	32	14	119	-60.2	40	20	118	-60.3	58	11	122	-65.4	37
16,000.....	23	100	-56.9	58	22	107	-63.5	29	19	106	-62.3	40	11	106	-67.5	32	13	101	-60.6	40	15	101	-60.7	58	9	105	-69.8	37
17,000.....	18	85	-57.4	58	18	91	-64.6	29	18	90	-62.9	40	9	89	-70.4	32	11	86	-61.2	40	15	86	-68.7	58	7	86	-72.2	37
18,000.....	16	72	-57.5	58	14	77	-64.6	29	12	76	-63.0	40	6	75	-68.5	32	8	72	-60.4	40	13	73	-69.8	58	6	73	-72.2	37
19,000.....	11	62	-57.7	58	13	65	-63.5	29	9	65	-62.2	40	6	63	-65.5	32	6	61	-60.1	40	8	62	-69.9	58	6	63	-72.2	37
20,000.....	6	52	-57.7	58	9	55	-61.1	29	6	55	-62.2	40	6	53	-65.5	32	6	53	-60.2	40	6	53	-60.2	58	6	53	-72.2	37

1 Navy.

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

NOTE.—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

Number of observations refers to pressure only as temperature and humidity data are missing for some observations at certain levels also the humidity data is not used in daily observations when the temperature is below -40° C.

TABLE 2.—Free-air resultant winds (meters per second) based on pilot-balloon observations made near 5 a. m. (E. S. T.) during November 1938

[Wind from N=360°, E=90°, etc.]

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,534 m)		Atlanta, Ga. (302 m)		Billings, Mont. (1,095 m)		Boston, Mass. (15 m)		Brooklyn, N. Y. (15 m)		Cheyenne, Wyo. (1,573 m)		Chicago, Ill. (192 m)		Cincinnati, Ohio (187 m)		Detroit, Mich. (204 m)		Fargo, N. Dak. (283 m)		Houston, Tex. (21 m)		Key West, Fla. (11 m)		Medford, Oreg. (410 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface.....	317	1.7	357	1.1	264	3.9	276	2.3	272	1.5	285	5.0	224	2.4	177	0.7	216	3.3	300	0.9	63	0.8	58	3.6	156	0.6
500.....	179	1.6	179	1.6	272	6.3	272	6.3	269	4.5	272	6.3	236	8.3	217	6.4	236	8.8	309	3.6	167	3.1	80	7.9	158	1.7
1,000.....	256	1.6	256	1.6	272	6.8	266	6.9	266	6.9	272	6.8	247	11.5	243	9.9	242	11.0	307	6.8	214	3.3	92	6.2	154	1.2
1,500.....	257	3.7	257	3.7	275	11.0	270	9.1	258	9.2	275	12.6	255	12.6	253	9.5	257	10.5	297	8.7	280	3.3	101	4.6	190	2.1
2,000.....	296	3.3	261	6.0	297	11.0	271	9.3	267	9.4	282	6.8	257	12.9	267	11.7	262	11.7	297	10.9	281	4.6	107	3.7	285	2.0
2,500.....	284	5.4	264	6.5	302	11.2	278	10.0	273	10.8	285	11.1	275	12.9	258	11.5	262	11.0	291	12.3	268	6.0	108	2.2	290	4.2
3,000.....	284	8.2	265	6.9	300	12.3	273	11.6	268	10.6	290	10.8	275	12.9	250	12.3	257	10.4	292	11.0	273	7.4	67	2.4	320	5.2
4,000.....	283	12.5	260	4.0	299	10.2	273	11.6	268	10.6	290	10.8	275	12.9	250	12.3	257	10.4	292	11.0	273	7.4	67	2.4	320	5.2
5,000.....	289	10.7	260	4.0	299	10.2	273	11.6	268	10.6	290	10.8	275	12.9	250	12.3	257	10.4	292	11.0	273	7.4	67	2.4	320	5.2

Altitude (meters) m. s. l.	Nashville, Tenn. (194 m)		Oakland, Calif. (8 m)		Oklahoma City, Okla. (402 m)		Omaha, Nebr. (306 m)		Pearl Har- bor, Terr. of Hawaii <sup>1</sup> (68 m)		Pensacola, Fla. <sup>1</sup> (24 m)		St. Louis, Mo. (170 m)		Salt Lake City, Utah (1,294 m)		San Diego, Calif. (15 m)		Sault Ste. Marie, Mich. (198 m)		Seattle, Wash. (14 m)		Spokane, Wash. (603 m)		Washing- ton, D. C. (3 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface.....	182	2.4	58	0.3	209	1.6	237	0.5	237	0.5	54	3.1	210	2.5	146	1.9	33	0.5	145	1.1	151	1.0	209	1.2	300	1.3
500.....	211	6.5	11	3.1	207	4.5	284	2.9	284	2.9	97	2.5	243	7.4	353	1.0	353	1.0	216	4.3	172	3.5	226	3.1	262	4.8
1,000.....	227	8.0	4	3.7	243	8.2	281	6.6	281	6.6	179	1.4	253	9.5	359	1.5	359	1.5	245	8.7	188	1.6	226	3.1	261	5.2
1,500.....	233	7.7	342	2.7	262	6.7	287	7.7	287	7.7	220	2.5	266	9.9	175	2.3	312	1.7	244	10.5	220	1.8	256	4.9	261	7.3
2,000.....	245	8.3	343	3.5	261	8.4	282	7.9	282	7.9	234	3.5	262	10.6	219	1.7	287	2.6	238	10.5	209	3.2	258	6.1	262	8.6
2,500.....	263	9.8	343	3.8	261	8.9	286	9.4	286	9.4	264	2.3	262	11.7	283	3.5	303	3.8	250	11.7	256	4.6	278	6.2	272	8.3
3,000.....	262	10.9	335	4.3	279	10.3	281	11.4	281	11.4	256	3.3	272	10.8	299	5.6	309	5.1	264	4.2	284	4.2	297	7.0	267	11.7
4,000.....	254	10.9	307	4.5	260	11.8	277	12.0	277	12.0	256	3.3	277	7.9	313	9.4	310	5.3	264	4.2	284	4.2	297	7.0	267	11.7
5,000.....	254	10.9	307	4.5	260	11.8	277	12.0	277	12.0	256	3.3	277	7.9	313	9.4	310	5.3	264	4.2	284	4.2	297	7.0	267	11.7

TABLE 3.—Maximum free-air wind velocities (m. p. s.) for different sections of the United States, based on pilot-balloon observations during November 1938

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m), m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m), m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m), m. s. l.	Date	Station
Northeast <sup>1</sup>	45.3	W	1,940	13	Cleveland, Ohio	44.2	W	3,040	13	Cleveland, Ohio	43.2	W	5,800	20	Syracuse, N. Y.
East-Central <sup>2</sup>	55.8	WNW	2,500	14	Washington, D. C.	69.1	WNW	2,620	14	Washington, D. C.	50.0	WSW	8,200	22	Nashville, Tenn.
Southeast <sup>3</sup>	30.5	NNW	1,780	24	Spartanburg, S. C.	44.4	WSW	4,350	26	Atlanta, Ga.	48.8	WSW	6,150	25	Atlanta, Ga.
North-Central <sup>4</sup>	49.1	W	820	14	Detroit, Mich.	47.0	W	2,630	13	Detroit, Mich.	62.0	SW	8,570	3	Fargo, N. Dak.
Central <sup>5</sup>	43.0	SSE	2,080	12	Chicago, Ill.	46.0	SW	5,000	12	Wichita, Kans.	57.6	WSW	9,560	5	Wichita, Kans.
South-Central <sup>6</sup>	38.0	NNW	2,470	24	Ft. Worth, Tex.	48.0	WNW	4,630	7	Abilene, Tex.	55.0	WSW	7,570	13	Oklahoma City, Okla.
Northwest <sup>7</sup>	35.8	W	1,940	15	Havre, Mont.	44.2	N	4,820	18	Medford, Oreg.	57.6	NNW	9,820	5	Medford, Oreg.
West-Central <sup>8</sup>	32.2	WNW	2,480	30	Cheyenne, Wyo.	51.8	WSW	4,320	8	Reno, Nev.	66.0	NNW	6,430	17	Modena, Utah.
Southwest <sup>9</sup>	34.7	NNW	2,110	2	Burbank, Calif.	51.5	W	5,000	1	Las Vegas, Nev.	90.0	WSW	12,020	14	Winslow, Ariz.

<sup>1</sup> Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.<sup>2</sup> Delaware, Maryland, Virginia, West Virginia, southern Ohio, Kentucky, eastern Tennessee, and North Carolina.<sup>3</sup> South Carolina, Georgia, Florida, and Alabama.<sup>4</sup> Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.<sup>5</sup> Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.<sup>6</sup> Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and western Tennessee.<sup>7</sup> Montana, Idaho, Washington, and Oregon.<sup>8</sup> Wyoming, Colorado, Utah, northern Nevada, and northern California.<sup>9</sup> Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.

## RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in charge]

By BENNETT SWENSON

No floods occurred during November 1938 with the exception of a flood in the Chippewa River from the 6th to the 9th. This flood resulted from heavy rainfall during the first week of November averaging more than 3 inches

over the basin. The river crested at Durand, Wis., at 4 p. m. of the 7th with a stage of 13.0 feet, 2 feet above flood stage. The damage caused by this overflow is estimated at about \$5,000.

## WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, L. R. TANNERHILL in charge]

## NORTH ATLANTIC OCEAN, NOVEMBER 1938

By H. C. HUNTER

**Atmospheric pressure.**—Pressure averaged much lower than normal over north-central and northeastern regions, the mean at Reykjavik, Iceland, being 0.4 inch less than the normal. The center of the Icelandic low-pressure area lay to the eastward of the average November location. The southeastern area averaged above normal pressure, with notably high readings constantly from the 12th onward to the end of the month. At the Azores, pressure averaged about normal, low readings from the 3d to the 14th being balanced by higher readings after the latter date.

The western North Atlantic had pressure moderately above normal to northward of latitude 30°, but over the Greater Antilles pressure averaged a little below normal, the first 12 days of the month being marked by readings quite low for the latitude.

The extremes of pressure among dependable vessel reports at hand are 30.71 and 28.40 inches. The higher reading was recorded not far to southwestward of the western Azores during the forenoon of the 28th by the Dutch steamship *Amsterdam*. The low mark was noted on the American steamship *Black Gull*, about 4 p. m. of the 11th, close to 49° N., 37° W.

Table 1 shows that the island station at Reykjavik had pressure slightly lower than the low mark mentioned, the date of occurrence being the 27th. Furthermore, a read-

ing of 28.10 inches, uncorrected, has been reported from the North Sea, not far from Tynemouth, England, noted during the 23d on the British steamship *Lunula*.

TABLE 1.—Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, November 1938

Station	Average pressure	Departure	High-est	Date	Low-est	Date
	Inches	Inch	Inches		Inches	
Julianehaab, Greenland	29.41	-0.15	30.00	6	28.72	15
Reykjavik, Iceland	29.22	-0.40	29.86	9	28.38	27
Lerwick, Shetland Islands	29.38	-0.32	30.33	15	28.50	1
Valencia, Ireland	29.66	-0.23	30.18	15	28.73	23
Lisbon, Portugal	30.21	+0.17	30.45	17	29.77	10
Maderia	30.14	+0.13	30.36	29	29.80	8
Horta, Azores	30.15	+0.02	30.68	28	29.38	9
Belle Isle, Newfoundland	29.83	+0.06	30.36	27	28.90	14
Halifax, Nova Scotia	30.08	+0.13	30.62	26	29.26	27
Nantucket	30.12	+0.07	30.67	3	29.15	25
Hatteras	30.18	+0.07	30.47	29	29.59	24
Bermuda	30.17	+0.09	30.36	6	29.98	1
Turks Island	29.95	-0.04	30.10	14	29.71	7
Key West	30.01	-0.01	30.26	28	29.74	8
New Orleans	30.15	+0.05	30.62	28	29.77	18

NOTE.—All data based on a. m. observations only with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

**Cyclones and gales.**—November lived up to its reputation for being a stormy month over the North Atlantic. While most of the reports of winds of very great force come from northern waters east of the 50th meridian, yet there are interesting features to be noted of cyclones that occurred near American or West Indian shores.

Elsewhere in this issue is a description of a cyclone of the West Indian region, noted about the 6th to 10th. Save for brief periods over limited areas the winds were not very intense, but two vessels, near the Bahamas, noted force 11. A large proportion of the November lows of these waters advance toward the north or east, but during the life of this particular low the pressure was notably high around Bermuda, and the movement of the low, at first toward the northwest, was later toward the southwest. Chart IX shows the conditions on the 8th, also the track of the low.

About this time some whole gales were experienced in mid-Atlantic, but it was on the 11th that winds exceeding whole gale force were first noted there. On that day an intense cyclone was formed near  $50^{\circ}$  N.,  $30^{\circ}$  W., by the uniting of one low, which had moved slowly northward from near the Azores, with another which had come rapidly from Labrador. One vessel noted force 11 when somewhat to northeastward of the Grand Banks. The low traveled to Iceland and continued toward the northeast.

A strong cyclone which crossed the southern part of Hudson Bay on the 13th was central 2 days later between Labrador and southern Greenland; intense winds associated with the system were felt so far to southeastward that a vessel near the northeastern edge of the Grand Banks reported force 11 on that day. The low already was shifting its course toward the north, so there were practically no later vessel reports of high winds due to it.

Not quite a week later, when a large low system covered the waters near Greenland and Iceland, there was rapid development in the southern portion of the area of low pressure, a part of the ocean where vessels ply in considerable numbers. On the evening of the 21st this development had taken form, central near  $50^{\circ}$  N.,  $35^{\circ}$  W.; and thence there was rapid advance toward the east-northeast. Late on the 22d this cyclone was located not far to the westward of Ireland; on the 23d it was over the North Sea; and the next day it centered over the Scandinavian peninsula. The east-bound *General Gas-souin* and the west-bound *Black Heron* met winds of hurricane force between noon and midnight of the 22d,

when a few hundred miles to the southwestward of Ireland.

During the final week storm developments of note occurred near the American coast, there being two distinct storms, about 60 hours apart, showing much similarity in their behavior and their courses. Starting well to southward, these lows gained strength with great rapidity and moved at unusually high speed.

The earlier of these storms was central late on the 24th near Hatteras, and the next morning not far from the southern tip of Nova Scotia. Its advance to northeastward carried it to Iceland by the 27th. The third and final instance yet reported of force 12 this month over Atlantic waters was connected with this storm, the American liner *Scanmail* meeting such force late on the forenoon of the 26th, when near  $51^{\circ}$  N.,  $44^{\circ}$  W.

The other storm was central between Bermuda and Nantucket, but nearer Nantucket, early on the 27th. It likewise traveled northeastward, and was over northern Newfoundland the following day, then turned nearly northward to the vicinity of Cape Farewell.

*Fog.*—On the whole, fog was even less common than usual during November. Two widely separated  $5^{\circ}$  squares furnish the greatest number of reports, 7 days each; one is close to southeastern Newfoundland,  $45^{\circ}$  to  $50^{\circ}$  N.,  $50^{\circ}$  to  $55^{\circ}$  W., while the other is near Europe,  $45^{\circ}$  to  $50^{\circ}$  N.,  $10^{\circ}$  to  $15^{\circ}$  W. From the 20th meridian to the shores of Europe and the British Isles, notably in latitudes from  $35^{\circ}$  to  $50^{\circ}$ , there was rather more fog than normally occurs in November, the chief periods of occurrence being 3d to 6th and 14th to 18th.

The main steamship lanes to northern Europe yield practically no items of fog between meridians  $20^{\circ}$  and  $45^{\circ}$  west, and the Grand Banks region had often less than normal, especially south of  $45^{\circ}$ .

Near Nova Scotia and eastern New England fog was locally somewhat more prevalent than shown by averages of previous Novembers; but to the southwestward of Cape Cod there was scarcely any. Over the Gulf of Mexico and over all the North Atlantic to southward of  $35^{\circ}$  latitude fog was wholly lacking, so far as reports now at hand indicate.

## OCEAN GALES AND STORMS, NOVEMBER 1938

Vessel	Voyage		Position at time of lowest barometer		Gale began November	Time of lowest barometer November	Gale ended November	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN													
American Merchant, Am. S. S.	London	New York	46 21 N.	40 11 W.	2	4a, 3	4	29.17	SSW	WSW, 7	N	N, 9	SW-WNW.
Salinas, U. S. Navy	Norfolk	Houston	28 39 N.	92 40 W.	3	8p, 3	4	29.81	S	S, 4	NE	NE, 9	S-SW.
W. S. Rheem, Am. S. S.	Cristobal	Dunkirk	41 38 N.	37 30 W.	4	2a, 4	5	29.45	SSW	S, 6	SW	SSW, 9	S-SW.
Pipestone County, Am. S. S.	New York	Havre	45 02 N.	41 35 W.	4	8a, 4	4	29.29	NNE	NNE, 10	NNE	NNE, 10	S-NNE.
Susan V. Luckenbach, Am. S. S.	Cristobal	New York	24 40 N.	74 19 W.	5	Mdt, 5	7	29.85	ENE	ENE, 8	E	ENE, 8	Steady.
Coamo, Am. S. S.	New York	San Juan	23 10 N.	67 50 W.	5	3p, 6	6	29.81	ESE	E, 8	ESE	E, 8	E-SE.
Bacchus, Du. S. S.	do	La Guaira	23 58 N.	68 06 W.	5	4a, 7	7	29.68	ESE	E, 10	SE	E, 11	E-ESE.
Beemsterdijk, Du. S. S.	Havana	Vera Cruz	21 42 N.	90 48 W.	6	6a, 7	8	29.88	NW	ENE, 4	NNW	NNW, 9	NNW, 9.
Maravi, Pan. S. S.	Preston, Cuba	Boston	24 10 N.	74 37 W.	6	5p, 7	8	29.63	NE	ESE, 8	ESE	N, 11	NE-N-ESE.
Patrick Henry, Am. S. S.	Houston	Havre	26 00 N.	79 50 W.	6	5a, 8	11	29.74	NE	NE, 7	N	NNE, 8	NNE, 8.
Baja California, Hond. S. S.	Bluefields	New Orleans	19 12 N.	85 12 W.	8	6a, 8	9	29.84	N	N, 3	N	N, 6	N, 6.
American Farmer, Am. S. S.	London	New York	48 35 N.	33 36 W.	9	2a, 9	9	29.15	NW	NW, 6	N	NW, 9	NE-SW-NW.
Black Gull, Am. S. S.	Antwerp	do	50 18 N.	19 54 W.	9	6a, 9	9	29.63	SE	SW, 9	W	W, 9	SE-W.
Amapala, Hond. S. S.	New York	Santiago	20 48 N.	74 12 W.	7	7a, 9	8	29.81	E	SSE, 4	ESE	E, 9	SE-W.
Bonneville, Nor. M. S.	Antwerp	Searsport, Maine	52 12 N.	16 10 W.	9	10a, 9	9	29.25	SSE	S, 10	SW	S, 10	SSE-SSW.
Cranford, Am. S. S.	Rotterdam	Tampa	39 50 N.	29 25 W.	9	2p, 9	10	29.34	WSW	WNW, 10	NW	WNW, 10	WSW-NNW.
Bilderdijk, Du. S. S.	do	Boston	47 17 N.	50 07 W.	11	2a, 11	11	29.32	NW	W, 7	NNW	NNW, 10	W-NW.
Capillo, Am. S. S.	Dundee	do	50 36 N.	38 32 W.	11	Noon, 11	12	28.60	NE	NW, 8	N	NNW, 9	N-NW-NNW.
Bonneville, Nor. M. S.	Antwerp	Searsport, Maine	52 19 N.	28 50 W.	12	2p, 11	12	28.62	N	Var. 2	NNW	NNW, 10	S-N.
Mormacsun, Am. S. S.	Copenhagen	New York	54 52 N.	35 50 W.	9	2p, 11	12	28.78	NE	NNE, 9	NNW	NNE, 10	W-N.
Black Gull, Am. S. S.	Antwerp	do	48 36 N.	36 54 W.	11	4p, 11	12	28.40	W	W, 8	NW	N, 10	NW-N.
Black Condor, Am. S. S.	New York	Antwerp	49 34 N.	39 36 W.	10	6p, 11	12	28.66	WNW	N, 11	NNW	N, 11	NW-N.
West Hobomac, Am. S. S.	New Orleans	Liverpool	42 03 N.	44 22 W.	13	2p, 13	14	29.66	NW	NW, 8	NNW	NW, 10	None.
Pres. Roosevelt, Am. S. S.	New York	Cobb	45 27 N.	32 24 W.	14	Noon, 14	14	29.17	NNW	NW, 8	NW	NW, 10	None.
Mormacsun, Am. S. S.	Copenhagen	New York	45 36 N.	55 06 W.	14	8p, 14	15	29.27	S	W, 6	W	WNW, 10	S-W.
Exiria, Am. S. S.	New York	Casablanca	39 46 N.	50 00 W.	14	3a, 15	15	29.83	SSE	SW, 9	SW	SW, 10	S-SW.
Bonneville, Nor. M. S.	Antwerp	Searsport, Maine	49 05 N.	47 21 W.	14	4a, 15	15	29.26	SW	WSW, 10	WSW	SW, 11	SW-WSW.
Collamer, Am. S. S.	Havre	New York	49 34 N.	29 24 W.	17	10p, 17	18	29.47	SSW	SSW, 7	W	NW, 9	SSW-NW.
Patrick Henry, Am. S. S.	Houston	Havre	48 20 N.	25 30 W.	18	6a, 21	21	29.57	SW	W, 8	NW	W, 9	WSW-NW.
General Gassoulin, Fr. M. S.	New York	Antwerp	48 46 N.	25 15 W.	22	2p, 22	22	29.17	WSW	W, 10	NW	WNW, 12	WSW-NW.
American Banker, Am. S. S.	Havre	New York	49 40 N.	20 38 W.	22	7p, 22	23	28.97	W	W, 10	NW	W, 10	SW-NW.
Black Heron, Am. S. S.	Antwerp	do	50 36 N.	19 03 W.	22	9p, 22	24	28.71	SW	W, 12	WSW	W, 12	SSW-NW.
Edam, Du. S. S.	Plymouth	do	49 49 N.	15 53 W.	22	Mdt, 22	23	28.81	SW	WSW, 10	NW	WSW, 10	WSW-WNW.
Schuykill, Br. M. S.	Aruba	Swansea	49 00 N.	12 15 W.	20	4a, 23	23	29.21	NW	W, 10	NW	W, 10	WSW-W.
Borinquen, Am. S. S.	New York	San Juan	37 20 N.	72 30 W.	25	7a, 25	25	29.41	WSW	WSW, 6	N	WNW, 9	WSW-NW.
Collamer, Am. S. S.	Havre	New York	41 45 N.	65 00 W.	25	8a, 25	25	29.00	SW	SW, 7	NW	WSW, 10	WSW-NW.
Seannail, Am. S. S.	Copenhagen	do	51 18 N.	44 08 W.	26	11a, 26	27	28.95	SW	SW, 11	W	SW, 12	SW-NW.
Pres. Roosevelt, Am. S. S.	Cobb	do	50 01 N.	17 34 W.	27	8a, 27	28	29.56	W	SW, 6	W	WNW, 10	SW-W.
American Banker, Am. S. S.	Havre	do	44 50 N.	50 28 W.	28	4a, 28	28	29.71	SE	SSW, 8	SSW	SSE, 10	SSE-SSW.
Caledonia, Br. S. S.	Belfast	Boston	55 20 N.	16 37 W.	27	5a, 28	29	28.75	S	WSW, 9	W	W, 10	S-SW.
Lewis Luckenbach, Am. S. S.	Cristobal	New York	24 30 N.	74 18 W.	29	3a, 29	30	30.03	NE	NE, 10	NE	NE, 10	SW-W.
Noordam, Du. M. S.	Rotterdam	do	49 43 N.	20 07 W.	29	Noon, 29	30	29.38	WSW	WSW, 8	W	W, 10	S-WSW.
Caledonia, Br. S. S.	Belfast	Boston	54 35 N.	23 35 W.	29	6p, 29	* 1	29.00	SSE	W, 9	WNW	WSW, 10	SW-W.
NORTH PACIFIC OCEAN													
Tatuno Maru, Jap. S. S.	Los Angeles	Yokohama	30 56 N.	175 35 W.	* 30	4a, 31	2	29.64	S	SW, 7	NE	NNF, 8	S-W.
Bengalen, Du. M. S.	Manila	Portland, Oreg.	35 55 N.	154 00 W.	2	6p, 2	2	29.87	N	NE, 8	NE	NNE, 8	N-NE.
Toa Maru, Jap. M. S.	Estero	Genzan	34 53 N.	166 21 W.	3	4p, 2	3	29.45	N	S, 4	N	N, 8	N-NE.
Zuiko Maru, Jap. S. S.	Sasebo	San Francisco	49 45 N.	172 30 W.	3	8p, 3	4	29.41	WNW	Var. 1	WSW	WNW, 8	ESE-Var-W.
Mapele, Am. S. S.	Hilo	do	36 42 N.	125 30 W.	5	4p, 5	5	30.16	N	N, 7	N	N, 8	N-NE.
Shoyo Maru, Jap. S. S.	Yokohama	Los Angeles	40 42 N.	159 23 E.	5	4a, 6	7	29.22	W	N, 7	W	W, 8	NE-N-W.
Wichita, Am. M. S.	Shanghai	Singapore	15 07 N.	115 52 E.	5	4p, 6	8	29.56	ENE	E, 7	SW	E, 8	E, 8.
North Sea, Am. S. S.	Prince Rupert	Seattle	53 24 N.	129 18 W.	6	4p, 6	6	29.78	SE	SE, 8	SE	SE, 8	SE, 8.
Bengalen, Du. M. S.	Manila	Portland, Oreg.	40 36 N.	174 10 E.	6	8p, 6	6	29.64	SE	SSE, 8	SSW	SSE, 8	SSE-SSW.
Empress of Asia, Br. S. S.	Victoria, B. C.	Yokohama	46 43 N.	160 56 E.	6	8p, 6	6	29.41	E	NE, 10	NE	NE, 10	ENE-NE.
Barrgrove, Br. S. S.	Milke	Singapore	19 28 N.	115 01 E.	7	3p, 7	9	29.61	NE	NNE, 8	SE	NE, 8	None.
Walter A. Luckenbach, Am. S. S.	Balboa	Los Angeles	14 24 N.	93 17 W.	8	Mdt, 7	8	29.73	NW	NW, 4	NE	N, 9	None.
Jefferson Myers, Am. S. S.	do	San Diego	15 12 N.	93 24 W.	8	2p, 8	9	29.75	NNW	NNW, 6	N	N, 9	None.
Bengalen, Du. M. S.	Manila	Portland, Oreg.	46 38 N.	159 40 W.	9	4p, 9	9	29.71	SSE	SSE, 8	S	S, 8	SSE-S.
Calmar, Am. S. S.	Los Angeles	Balboa	14 48 N.	95 06 W.	9	4a, 10	10	29.80	E	NNE, 7	N	NE, 7	ENE-N.
Kaijo Maru, Jap. M. S.	Port San Luis	Dairen	34 18 N.	163 45 E.	10	7a, 10	10	29.23	WSW	WSW, 9	NNW	WNW, 10	WSW-WNW.
Nitsei Maru, Jap. M. S.	Balik Papan	Tokuyama	14 30 N.	124 60 E.	12	4a, 12	14	29.69	NNW	N, 7	NE	N, 9	NNW-N.
Bengalis, Du. S. S.	Manila	Los Angeles	17 06 N.	119 48 E.	12	8p, 12	15	29.84	NNE	NNE, 7	NE	NE, 9	NNW-N.
Kaijo Maru, Jap. M. S.	Port San Luis	Dairen	32 54 N.	150 27 E.	13	6a, 13	13	29.48	W	W, 7	W	W, 8	NW-W.
Athelsultan, Br. M. S.	Gensan	El Segundo	41 00 N.	163 10 E.	13	10a, 13	13	29.26	SE	SSE, 9	WSW	SSE, 9	SE-SW.
Toorak, Br. S. S.	Saitozaki, Japan	Los Angeles	49 38 N.	178 36 E.	13	6a, 14	15	28.76	E	SSE, 9	W	WSW, 10	ESE-S.
do	do	do	48 30 N.	161 34 W.	16	8a, 16	16	29.57	SE	S, 9	SW	S, 9	SE-SSW.
China Arrow, Am. S. S.	Nagasaki	do	51 03 N.	172 15 W.	18	10p, 18	19	29.35	S	SSE, 11	SSW	SSE, 11	SSE-SSW.
Georgian, Am. S. S.	Balboa	do	13 06 N.	90 48 W.	20	6p, 19	20	29.70	N	NW, 4	N	N, 8	SSE-S.
Maunawili, Am. S. S.	Honolulu	San Francisco	30 55 N.	140 51 W.	21	2a, 22	23	29.77	SSE	SE, 8	SE	SE, 8	SSE-SE.
Bengalis, Du. S. S.	Los Angeles	do	38 30 N.	155 30 E.	22	10p, 21	22	29.63	ESE	ESE, 7	NW	NW, 8	NW, 8.
do	do	do	40 30 N.	170 30 E.	23	11a, 24	24	29.89	S	W, 6	SW	WSW, 9	WSW, 9.
San Ramon Maru, Jap. M. S.	Yokohama	San Pedro	40 25 N.	178 15 W.	26	5p, 25	25	29.28	S	SW, 8	SW	S, 8	S-WSW.
Bengalis, Du. S. S.	Manila	Los Angeles	40 06 N.	173 54 W.	25	Mdt, 25	27	29.30	S	SSW, 9	WNW	SSW, 9	S-W.
Hopecrest, Br. M. S.	Cebu, P. I.	do	36 45 N.	179 39 E.	27	Noon, 28	28	29.64	NW	SW, 6	NW	NW, 9	S-W.
San Ramon Maru, Jap. M. S.	Yokohama	San Pedro	40 30 N.	161 05 W.	28	1p, 28	29	28.79	SSE	WSW, 11	NW	NW, 12	SW-NW.
Bengalis, Du. S. S.	Manila	Los Angeles	40 06 N.	157 00 W.	28	2p, 28	30	29.03	WSW	WSW, 9	SW	WNW, 9	WSW-WNW.

\* Position approximate.

\* Barometer uncorrected.

\* December.

\* October.

## NORTH PACIFIC OCEAN, NOVEMBER 1938

By WILLIS E. HURD

**Atmospheric pressure.**—Pressure over practically all parts of the North Pacific Ocean averaged higher in November 1938 than in the preceding month. At Kodiak the pressure was three-tenths of an inch higher than in October. In November the central area of the Aleutian Low lay over the eastern Aleutians and the southeastern part of Bering Sea, with the lowest average pressure, 29.52 inches, at St. Paul. The lowest recorded barometer reading of the month was 28.20 inches, at Kanaba Island, central Aleutians, on the 26th. Centers of high pressure lay off the California coast and in lower midocean near Midway Island.

TABLE 1.—Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, November 1938, at selected stations

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow	29.80	-0.10	30.42	8	29.12	15
Dutch Harbor	29.57	-0.02	30.16	18	28.52	27
St. Paul	29.52	-0.07	30.20	7	28.64	14, 24
Kodiak	29.62	+0.06	30.44	20	28.92	15
Juneau	29.85	+0.09	30.65	25	28.98	15
Tatoosh Island	30.11	+0.14	30.59	22	29.43	1
San Francisco	30.14	+0.05	30.37	7	29.86	28
Mazatlan	29.90	+0.01	30.02	20, 30	29.80	1, 5
Honolulu	29.99	-0.03	30.15	29	29.84	4
Midway Island	30.12	+0.04	30.30	29	29.94	10
Guam	29.84	-0.02	29.92	11, 12, 13	29.74	9, 18
Manila	29.83	-0.00	29.92	12, 17	29.71	4
Hong Kong	30.05	+0.01	30.22	13	29.84	6, 7
Naha	30.09	+0.11	30.21	17	29.86	6
Titilima	30.01	+0.03	30.15	14, 22, 30	29.80	24
Petrovsk	29.71		30.39	8	29.35	26

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

**Extratropical cyclones and gales.**—Despite the nearer approach to the winter season, storminess on the North Pacific in November was less severe and widespread than in the preceding month, and during the first week only one gale in excess of force 8 was reported by an observing ship. That was a wind of force 10 encountered by the British S. S. *Empress of Asia* in a cyclone east of the Kuril Islands on the 6th. Aside from this cyclone, the only other of importance during the first week was one that lay northeast of Midway Island during the first 4 days and caused force-8 gales on the 1st to 3d.

A chart of the month's extratropical gales thus far reported shows that practically all of them occurred between the meridians of 150° E. and 150° W., the exceptions being fresh gales in the following localities: On the 5th in a high pressure area off the coast of central California; on the 16th off the coast of British Columbia in a depression lying over the extreme northeastern part of the ocean; and on the 22d, near 31° N., 141° W., in connection with the month's long-continued low pressure trough lying about midway along the routes between California and the Hawaiian Islands.

Between the 6th and the 14th only one gale of force as high as 10 was reported from extratropical waters. This occurred on the 10th and was encountered by the Japanese M. S. *Kaijo Maru* near 34° N., 164° E., with barometer 29.23, in the midst of a low pressure system of great extent.

On the 14th and 15th a cyclone overspread high latitudes, with pressures below 29 inches extending over the Gulf of Alaska, the eastern part of the Bering Sea, and the region of the central Aleutians. Among the few ships

to report gales in connection with the great disturbance was the eastbound British S. S. *Toorak*. During the 14th this ship encountered winds of force 9-10 for several hours. Her lowest barometer was 28.76 on the same date near 49½° N., 178½° E. It was the *Toorak* that, singularly enough, encountered the next following gale reported in high latitudes, a wind of force 9, near 48½° N., 161½° W., on the 16th.

On the 18th a tongue of high pressure extended northward over the eastern Aleutians and the Peninsula of Alaska. Pressure fell sharply to the west and southwest of Dutch Harbor, and along the steep gradient thus formed, the winds became of locally high intensity, the American S. S. *China Arrow* experiencing a south-southeast gale of force 11, barometer 29.35, late on the 18th, near 51° N., 172° W.

From the 23d to the end of the month the entire Aleutian region was covered by a deep cyclone, with central pressures for the most part below 29 inches, and with a minimum depth on the 26th of 28.20 inches. Despite the low barometer the accompanying gales for the most part were not severe and occurred, according to ships' reports, at a great distance south of the center. On the 23d to 26th vessels in the vicinity of the 40th parallel, between about 170° E. and 170° W., reported gales, but not stronger than force 9. On the 28th, however, the Japanese S. S. *San Ramon Maru* encountered rapidly rising winds in the early afternoon in 40°30' N., 161°05' W., barometer 28.79. At 5 p. m. the gale, from the northwest, had risen to hurricane strength, the only instance of a force-12 wind thus far reported for November from middle and higher latitudes of the North Pacific. The final gales reported for the month were of force 8 to 9, occurring in the same locality during the early morning of the 29th.

**Cyclones and gales of the Tropics.**—On November 3 a shallow depression appeared over the southern Philippines, moving westward. On the 4th, in the eastern part of the China Sea, it moved northwesterly and on the 6th to 8th lay in the vicinity of Hainan Island, where it was of considerable depth and caused gales which are shown on our charts to have attained force 8 to 9. Thereafter the storm appears to have dissipated.

On the 6th and 8th fresh east to northeast gales, accompanied by barometer readings of about 29.60 inches, occurred in the eastern part of the China Sea, associated with a depression west of the Philippines.

On the 13th a small low, with no apparent antecedent or subsequent history, appeared in Philippine waters. In connection with this disturbance, the Japanese M. S. *Kitiei Maru* reported a north gale of force 9, in 14°30' N., 124°50' E. On the same day the Dutch S. S. *Bengkalis* encountered a northeast gale of force 9, lowest barometer 29.84, close to the west coast of northern Luzon. A strong northeast monsoon current was blowing at the time along the east China coast and as far southward as northern Philippine waters.

A report on the typhoons and depressions of the Far East for the current month is expected from the Weather Bureau at Manila.

**Tehuantepecers.**—Northerly winds of this type were reported in the Gulf of Tehuantepec as follows: Of force 7 on the 10th and 27th; of force 8 on the 20th; and of force 9 on the 8th and 9th.

**Fog.**—Ships' reports show the occurrence of fog in east longitudes on only 1 day. In west longitudes, within the area 35° to 50° N., 135° to 175° W., fog was reported on 13 days, but in no single 5° square on more than 3 days. In coastal waters it was observed on 1 day off the Washington coast and on 6 days off the California coast.

# TYPHOONS AND DEPRESSIONS OVER THE FAR EAST, NOVEMBER 1938

BERNARD F. DOUCETTE, S. J.

[Weather Bureau, Manila, P. I.]

*Typhoon, November 1-11, 1938.*—A depression appeared November 1 about 120 miles southwest of Yap, moved west-northwest to latitude 10 where it changed its course to the west, increasing in strength as it proceeded. It approached Surigao Strait during the forenoon hours of November 4, crossed northern Leyte on a west by north course, continued on to Panay Island and entered the extreme northern portion of the Sulu Sea. As the storm approached the China Sea, it passed north of Cuyo and south of Culion, moving west by north and inclining to the west.

The morning weather map, November 5, showed the center to be about 60 miles west-southwest of Culion and very much stronger. It continued along a westerly course during the forenoon and changed to the west-northwest and northwest during the afternoon and evening, thus approaching the Paracel Islands and Reefs, where it moved in a northerly direction, but more slowly. On November 8, it changed to the west, inclined to the northwest, passed over Hainan Island and disappeared over the Gulf of Tong King.

As this disturbance passed over the Visayan Islands on its way from the Pacific Ocean to the China Sea, the strongest winds reported were those from the east-southeast or southeast after the center had passed the locality. At noon, Manila time, the S. S. *Taurus* reported "latitude 11°50' N. longitude 125°40' E., barometer 29.62, temperature 81, winds east-southeast 8, fresh gales from east-southeast, very heavy sea"; the center being at this time about 100 miles south-southwest of the ship's position. At 6 p. m. Manila time, Tacloban, Leyte, had east-southeast winds force 7, when the center was about 150 miles west of the locality. The lowest pressures reported were between 748 and 750 mm (29.449 and 29.528 in.) with winds not exceeding force 5 over regions adjacent to the center. For example, Capiz and Iloilo, both on Panay Island, had pressures of 749.6 mm (29.512 in.); Capiz with east-northeast winds force 4 and Iloilo with west winds force 2 (6 p. m. Manila time), the center being between the two stations. However, considerable rain fell while this storm was crossing the Archipelago, but no extensive damage was reported.

Intensification of the storm in the China Sea is best shown by the weather reported from the Paracel Island station. Winds backed from north-northeast to north-northwest, west-northwest, and west-southwest, as the storm center passed about 100 miles east-northeast of the station, on its northwesterly course. The winds were force 9 and the lowest barometer reported for synoptic purposes was 744.4 mm (29.308 in.) at 6 a. m. November 7.

During the formation of this disturbance, the upper winds from the U. S. Navy Station at Guam showed the presence of air streams from east-northeast and east directions with velocities about 30 k. p. h., which, after November 1, gradually shifted to the east-southeast, as velocities increased to values close to 50 k. p. h. As the disturbance approached and crossed the Philippines, there was scarcely any evidence of a southwest monsoon current. Only until the center entered the China Sea did southwest quadrant winds appear at Zamboanga. The remaining Philippine aerological stations had Northeast quadrant winds shifting to the southeast as the center moved toward

the China Sea, velocities between 50 and 80 k. p. h. being reported from Manila and Cebu.

*Depression, November 10-18, 1938.*—About 300 miles south-southwest of Guam a depression appeared on November 10, moved west by north, then west to the regions about 400 miles east of Samar Island. There it recurved to the northeast, November 12, changing to north, then north-northeast, and moving more rapidly as it proceeded. Observations were not available for determining its history after it reached the ocean regions east of northern Japan, November 18. Furthermore, as well as could be determined from available data, the storm was not of very great intensity over a wide area.

At Guam, the upper winds during the formation of this depression veered from east and east-northeast directions, with velocities between 30 and 50 k. p. h., to the southeast, increasing to values as high as 70 k. p. h., as the depression moved west-northwest between that station and Yap. The air streams over the Philippines and the China Sea as the depression recurved (November 12) showed that the southwest winds which started with the preceding typhoon were extending toward the Pacific by way of Zamboanga, but were checked by a strong outbreak of northerly air, caused by a distant depression in the locality of Japan. This current of cool heavy air reached San Bernardino Strait and most likely caused the Pacific depression to recurve, as well as checking the southwest winds which were gradually strengthening over Zamboanga.

*Typhoon, November 21-27, 1938.*—A disturbance appeared about 250 miles west-northwest of Palau, moved westerly, then northwesterly, to the 10th parallel of latitude where it changed its course to the west, moving rapidly across the Visayan Islands as a depression. The morning of November 24 found the center located about 60 miles west of northern Palawan, already intensifying into a typhoon. Continuing along a westerly course for a day, it then shifted to the west-northwest when about 300 miles east of southern Indo China. It entered Indo China near Quinhon on the afternoon of November 27, after which no trace of it could be found.

On November 23, this disturbance crossed the Visayan Islands as a widely extended depression, with no definite center, with weak variable winds, and pressure values between 753 and 754 mm. (29.646 and 29.686 in.), on the morning map, and between 752 and 753 mm. (29.607 and 29.646 in.), on the afternoon map. Zamboanga reported the strongest winds, west-southwest force 4, from the southern Philippine stations during this period. Over northern Luzon, however, very heavy rains set in especially along the coast and over the length of the Cagayan River, these rains caused by strong northeast monsoon winds with a southeasterly current aloft. Extensive destructive floods resulted, but with hardly any loss of life.

Observations from the S. S. *Tjisaroea* and S. S. *Silvermaple* show the intensification of this storm, once it reached the regions of the China Sea. These ships were hove to about 150 to 200 miles from the storm center as it approached the southern coast of Indo China, November 25 and 26. They had winds of force 9 (the *Silvermaple* reporting force 11 once) from the northwest quadrant, and backing to the west-southwest as the center moved north of their positions. Pressure values were between 749.3 and 751.5 mm (29.501 and 29.587 in.) during this period. Ships over the northern part of the China Sea reported northeast winds force 5, 6, and 7 as the typhoon moved from the Philippines to Indo China. It can be seen that the storm intensified to a typhoon of considerable power once it moved away from the Philippines.

The pilots of November 18 to 20 indicated the existence of two currents, one from the east, velocities from 30 to 50 k. p. h., the other from the west, velocities 20 to 40 k. p. h. and the equatorial regions separating these currents. The easterly current, as shown by pilots from Guam, increased in strength and very likely the westerly current over Java and Sumatra acted the same way. It was a situation where a disturbance might form, except for the fact that the region of formation was too close to the equator. It is a period very interesting to study, for the activity of the air streams can be examined without the complications of a violent typhoon interfering. After the disturbance formed west-northwest of Palau, the two currents continued in existence, that over Java being very strong, judging by the upper winds from Batavia, which were consistently (as often as reported) over 50 k. p. h. When, on November 24 and 25, the center reached the China Sea, and the rapid intensification began, the upper winds over Zamboanga changed to the southwest and south quadrants, with velocities up to 60 k. p. h., thus indicating that the westerly winds over Java might be deflected to the regions of the Celebes Sea and the southern part of the Sulu Sea. Usually the southwest monsoon air reaches the typhoon center after passing over the regions of the Straits Settlements, but, from the few pilots available at present writing, it seems that the intensification of this typhoon took place as described above.

*Typhoon, November 26-December 2, 1938.*—As a depression, this storm moved from the ocean regions between Mindanao and Palau along a west-northwesterly course, inclining to the northwest as the center approached Samar Island. It gave evidence of having typhoon strength as it moved along this course over northern Samar and across the western part of San Bernardino Strait during the night of November 28 and the morning hours of November 29. It inclined to the west by north as it moved across the northern Visayan Islands, but, in the China Sea, it had

a west-northwest inclination. Until the afternoon hours of December 1, it moved west-northwest, when it changed to the west, then southwest, passing about 100 miles south of the Macles Field Reefs. During the night of December 2, the storm disappeared over southern Indo China.

As this storm crossed the Archipelago, it could be classified as a typhoon of moderate intensity; as the lowest barometer reading reported for the weather maps was 749.2 mm. (29.497 in.), from Boac, Marinduque, and three stations had winds of force 6, namely Masbate, direction southwest, Atimonan, direction north, and Batangas, direction east. In the China Sea, however, it did not manifest the power of the previous storm. A very significant observation was that of the S. S. *Conte Verde* December 1, 2 p. m. Manila time, from latitude  $16^{\circ} 47' N$ , longitude  $110^{\circ} 41' E$ , barometer 750 mm. (29.528 in.), winds north-northeast force 6, steady, sea 6, swell none, visibility 6, weather cloudy. (At the time, the typhoon was located near latitude  $15^{\circ}$ , longitude  $115^{\circ}$ ).

It is probable that the southwesterly current starting with the previous typhoon moved up to Surigao and locality and then into the Pacific Ocean, where interaction took place with the easterly current over those regions. This may have been a contributing factor to the formation of the disturbance.

The three China Sea typhoons of this month exemplify the statement made by Jeffries and Heywood in "The Law of Storms in the China Sea" 1938, (p. 23), that the westerly current, which begins during the month of October at heights above 6,000 to 10,000 feet, does not allow a typhoon center to approach the locality from the east. During the whole month of November, the pilots from Indo China and Hong Kong indicated that this high westerly current was in existence and, at the same time, the three typhoon centers did not seriously threaten northern Indo China and Hong Kong.

## CLIMATOLOGICAL TABLES

## CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE 1.—Condensed climatological summary of temperature and precipitation by sections, November 1938

[For description of tables and charts, see REVIEW, January, p. 20]

Section	Temperature								Precipitation							
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly			
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount		
	°F.	°F.		°F.				°F.		In.	In.		In.		In.	
Alabama.....	56.5	+2.1	3 stations.....	89	13	2 stations.....	11	28	3.35	-0.06	Haleyville.....	7.07	Columbia.....	0.25		
Arizona.....	46.2	-4.5	2 stations.....	91	11	Fort Valley.....	-4	13	.06	- .05	Fort Valley.....	.72	59 stations.....	1.00		
Arkansas.....	50.7	- .7	Lutherville.....	89	2	Lead Hill.....	8	27	5.26	+1.51	Magnolia.....	9.60	Wilson.....	1.30		
California.....	49.0	-3.2	San Jacinto.....	90	17	Boca.....	-11	12	1.17	-1.24	Elk Valley.....	10.32	24 stations.....	.00		
Colorado.....	30.5	-4.6	Long Branch.....	87	1	Fraser.....	-27	26	.93	+ .14	La Veta Pass.....	3.28	Manassa.....	T		
Florida.....	67.1	+2.1	Ocala.....	94	5	Vernon.....	15	29	1.61	- .60	West Palm Beach.....	7.06	Cedar Keys.....	.21		
Georgia.....	57.1	+2.6	3 stations.....	88	16	Blairsville.....	7	28	2.71	+ .06	Clayton.....	7.70	Camilla.....	.34		
Idaho.....	29.8	-5.6	Lewiston.....	66	3	Island Park Dam.....	-26	23	1.91	- .16	Roland.....	7.30	Grouse.....	.07		
Illinois.....	44.8	+2.7	Mount Vernon.....	86	1	Marengo.....	3	25	2.35	- .26	Waterloo.....	6.15	Kankakee.....	.87		
Indiana.....	45.2	+2.9	Shoals.....	86	11	Goshen.....	-1	25	3.00	- .06	Greensburg.....	5.46	Decatur.....	.83		
Iowa.....	37.6	+1.4	6 stations.....	83	1	Sibley.....	-8	27	2.76	+1.15	Oskaloosa.....	5.25	Cushing.....	.85		
Kansas.....	42.6	- .6	4 stations.....	83	1	4 stations.....	-2	22	1.40	+ .12	Anthony.....	6.39	Kismet (near).....	T		
Kentucky.....	47.9	+1.4	Ashland.....	83	7	Heidelberg.....	2	25	3.68	+ .26	Quicksand.....	8.09	Murray.....	1.77		
Louisiana.....	57.9	-1.0	2 stations.....	89	13	Tallulah.....	15	28	4.03	+ .20	Plain Dealing.....	8.27	New Orleans (Shushan).....	1.31		
Maryland-Delaware.....	48.0	+2.9	Western Port, Md.....	85	7	Oakland, Md.....	-8	26	2.79	+ .33	Emmitsburg, Md.....	4.11	College Park, Md.....	1.58		
Michigan.....	39.2	+2.2	Bloomington.....	79	2	Dukes.....	-12	25	1.64	- .95	Haughton.....	5.21	Flint.....	.21		
Minnesota.....	27.7	-1.8	Artichoke Lake.....	83	1	Hallock.....	-27	24	1.90	+ .74	Grand Rapids.....	5.38	Hallock.....	.41		
Mississippi.....	55.2	+ .1	Bay St. Louis.....	90	2	2 stations.....	14	28	3.30	- .32	Port Gibson.....	5.82	2 stations.....	1.80		
Missouri.....	49.9	+1.5	Warsaw.....	89	1	Grant City.....	2	27	4.28	+1.60	Richwoods.....	9.26	St. Joseph.....	1.90		
Montana.....	28.9	-3.2	5 stations.....	61	18	Conway's Ranch.....	-21	23	.89	- .07	Summit.....	4.27	Harlowton (near).....	.11		
Nebraska.....	35.9	-1.3	Pawnee City.....	83	2	Nanzel (near).....	-9	22	.72	- .04	Tecumseh.....	3.54	5 stations.....	.00		
Nevada.....	35.5	-4.4	Las Vegas.....	80	13	Golconda.....	-9	12	.52	- .12	Arthur.....	1.96	Searchlight.....	.00		
New England.....	40.6	+2.6	Fitchburg, Mass.....	80	7	White River Junction, Vt.....	-19	26	3.04	- .42	Hyannis, Mass.....	4.76	Fort Kent, Maine.....	1.22		
New Jersey.....	45.6	+2.0	Hammononton.....	80	6	Runyon.....	-7	26	3.42	+ .24	Burlington.....	5.10	New Milford.....	2.21		
New Mexico.....	38.4	-4.0	Carlsbad.....	88	5	Eagle Nest.....	-26	7	.27	- .37	Truchas.....	1.90	28 stations.....	.00		
New York.....	40.8	+2.7	Brookport.....	82	7	Indian Lake.....	-17	26	2.79	- .22	Knapp Creek.....	4.39	Peru.....	1.32		
North Carolina.....	52.9	+2.9	2 stations.....	88	16	Mount Mitchell.....	0	28	4.02	+1.36	Mount Mitchell.....	12.04	Wilmington.....	.92		
North Dakota.....	23.8	-2.8	McLeod.....	75	1	2 stations.....	-21	24	.87	+ .27	Berthold Agency.....	2.13	Hansboro.....	.14		
Ohio.....	44.1	+2.6	Gallipolis.....	89	7	McArthur.....	-3	25	3.19	+ .47	Norwalk.....	4.82	Montpelier.....	1.10		
Oklahoma.....	48.7	-1.0	4 stations.....	87	11	Hooker.....	0	24	2.21	+ .20	Webbers Falls.....	6.50	Beaver.....	.04		
Oregon.....	36.2	-4.2	Tiller.....	81	29	2 stations.....	-13	12	3.35	- .37	McNamers.....	12.56	Canyon City.....	.18		
Pennsylvania.....	42.7	+1.4	Bloomsburg.....	87	7	Somerset.....	-13	26	3.10	+ .23	Freeland.....	5.62	Bellefonte.....	1.35		
South Carolina.....	56.8	+3.0	Kingstree.....	87	14	2 stations.....	12	28	2.84	+ .51	Caesars Head.....	5.97	Charleston.....	.60		
South Dakota.....	30.7	-2.4	Menno.....	82	1	do.....	-14	22	.57	- .06	Canton.....	2.84	2 stations.....	T		
Tennessee.....	49.7	+1.1	Madisonville.....	85	2	Rugby.....	5	28	4.38	+ .80	Lynnville.....	7.61	Martin.....	1.59		
Texas.....	54.9	-2.2	Rio Grande.....	98	15	Muleshoe.....	2	24	1.50	- .68	Huntsville.....	7.95	8 stations.....	.00		
Utah.....	30.5	-6.9	3 stations.....	69	14	Silver Lake.....	-17	23	1.16	+ .22	Silver Lake.....	5.09	3 stations.....	.00		
Virginia.....	49.0	+2.8	Hopewell.....	84	19	3 stations.....	0	26	3.79	+1.37	Pinnacles.....	8.54	Cheriton.....	1.27		
Washington.....	37.2	-2.4	Okanogan.....	69	4	Bumping Lake.....	1	11	4.01	-1.41	Skykomish.....	20.47	Naches Heights.....	.16		
West Virginia.....	44.7	+1.5	2 stations.....	86	7	Bayard.....	-10	26	3.96	+1.20	Philippi.....	5.87	Knobly Mountain.....	1.89		
Wisconsin.....	34.5	+1.2	Wisconsin Dells.....	81	1	Solon Springs.....	-9	24	2.39	+ .53	Rest Lake.....	4.20	Danbury.....	1.11		
Wyoming.....	25.7	-5.9	LaGrange.....	69	1	West Yellowstone.....	-35	23	1.01	+ .30	Bechler River.....	4.80	Powell.....	.69		
Alaska (October).....	37.8	+7.8	Petersburg.....	72	19	Alakakeet.....	-2	31	1.68	-1.86	Little Port Walter.....	38.05	Nanana.....	.64		
Hawaii.....	72.4	+ .6	Maui.....	95	1	Kanaloahulu.....	44	22	5.20	-2.86	Piiponua.....	32.00	5 stations.....	.00		
Puerto Rico.....	75.9	- .7	2 stations.....	92	11	2 stations.....	50	29	13.08	+5.60	La Mina (El Yunque).....	35.76	San Sebastian.....	3.35		

1 Other dates also.

TABLE 2.—Climatological data for Weather Bureau stations, November 1938

(Compiled by Annie E. Small, by official authority, U. S. Weather Bureau)

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind					Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month							
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + min. +2	Departure from normal	Maximum	Date	Mean minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch or more	Average hourly velocity	Prevailing direction	Maximum velocity											
																							Miles per hour	Direction				Date						
New England																																		
Eastport	76	67	85	30.00	30.08	+0.07	40.0	+3.3	67	5	47	12	26	33	23	37	35	84	2.77	-0.6	12	11.6	sw.	42	n.	25	9	6	15	6.3	11.1	0.		
Greenville, Maine	1,069	4	41	29.00	30.11	+0.11	34.2	+4.0	73	7	44	-1	27	25	42	30	27	72	2.23	+0.2	14	9.1	nw.	34	nw.	25	13	8	9	4.7	16.5	7.8		
Portland, Maine	103	82	117	29.99	30.12	+0.13	41.2	+4.0	74	7	50	10	26	34	27	37	32	72	3.69	+0.2	14	8.2	n.	24	nw.	25	8	8	14	6.4	18.4	7.7		
Concord	289	54	72	29.81	30.14	+0.33	38.2	+3.6	78	7	51	-2	26	31	38	31	30	86	2.05	-0.9	14	7.3	sw.	26	sw.	8	7	7	10	6.6	12.7	4.0		
Burlington	403	11	48	29.65	30.10	+0.45	35.6	+2.8	74	7	46	-13	26	24	38	31	30	86	2.05	-0.9	14	11.8	s.	34	s.	22	8	8	17	7.2	7.3	1.5		
Northfield	876	12	60	29.15	30.11	+0.06	35.6	+2.8	74	7	47	-13	26	24	38	31	30	86	2.05	-0.9	14	7.3	sw.	26	sw.	8	7	7	10	6.6	12.7	4.0		
Boston	29	33	62	30.09	30.12	+0.03	46.4	+4.4	77	7	54	12	26	38	27	41	36	74	2.89	-0.4	10	11.6	sw.	39	nw.	25	9	6	13	6.1	10.0	2.7		
Nantucket	12	14	90	30.11	30.12	+0.01	48.8	+4.4	68	6	55	12	25	42	23	46	44	90	3.84	+0.6	13	15.5	n.	51	n.	25	18	6	9	4.6	-2	0		
Block Island	26	11	46	30.11	30.14	+0.03	48.2	+3.6	68	6	54	16	26	42	22	45	41	78	3.03	-0.6	10	17.1	w.	52	nw.	25	17	6	7	3.8	1.7	0		
Providence	159	215	251	29.96	30.14	+0.17	46.0	+5.6	74	7	54	10	26	38	25	41	37	76	3.40	+0.3	11	11.2	nw.	43	nw.	25	11	7	12	5.3	8.4	2.4		
Hartford	159	66	100	29.98	30.16	+0.18	44.2	+4.7	73	8	53	7	26	36	30	42	38	78	3.44	-0.1	11	8.4	s.	29	n.	25	8	11	11	5.7	15.6	10.3		
New Haven	106	74	153	30.04	30.16	+0.12	45.7	+3.7	74	7	54	11	26	38	28	42	38	78	3.44	+0.9	13	9.2	n.	32	n.	25	9	11	10	5.6	13.2	3.7		
Middle Atlantic States																																		
Albany	292	26	37	29.80	30.12	+0.32	40.0	+3.1	75	7	50	-11	26	31	33	36	33	81	2.38	-0.4	12	9.6	s.	34	w.	14	5	10	15	6.9	6.8	1.7		
Binghamton	871	57	79	29.20	30.15	+0.06	41.6	+2.9	76	7	52	0	26	32	37	37	34	79	2.52	+0.1	11	6.5	sw.	24	sw.	14	3	8	19	7.6	6.9	1.4		
New York	314	415	484	29.81	30.15	+0.34	40.0	+3.1	75	7	50	-11	26	31	33	36	33	81	2.38	-0.4	12	9.6	s.	34	w.	14	5	10	15	6.9	6.8	1.7		
Harrisburg	374	94	104	29.76	30.17	+0.06	47.7	+2.0	75	7	54	13	27	36	32	40	35	73	3.37	+0.6	11	6.9	s.	24	nw.	14	14	5	11	5.1	10.2	2.0		
Philadelphia	114	174	367	30.04	30.17	+0.13	48.6	+2.9	76	7	57	18	26	40	29	44	40	77	3.11	+0.4	12	12.7	w.	29	nw.	19	10	9	11	5.1	11.5	2.7		
Reading	323	283	306	29.82	30.18	+0.36	46.6	+4.1	74	7	56	12	26	37	36	41	35	69	3.14	+0.4	12	10.5	nw.	44	nw.	14	10	11	9	5.4	13.4	3.3		
Scranton	805	72	104	29.27	30.15	+0.06	42.8	+2.3	74	7	52	6	26	34	34	38	35	77	3.24	+0.5	11	6.4	sw.	30	nw.	15	10	8	12	5.6	12.2	3.0		
Atlantic City	52	37	172	30.11	30.17	+0.07	50.0	+4.4	69	6	57	20	28	43	24	46	43	80	3.59	+0.8	12	15.6	s.	40	n.	25	12	9	9	4.7	5.9	T		
Sandy Hook	22	10	57	30.12	30.13	+0.01	48.4	+2.6	73	7	54	22	26	43	22	44	40	78	4.74	+1.5	12	14.9	s.	44	w.	14	10	6	14	5.6	8.7	3.0		
Trenton	190	89	107	29.95	30.16	+0.21	46.5	+2.1	75	7	56	14	26	37	32	42	37	76	3.10	+0.4	12	8.4	s.	30	w.	14	9	8	13	5.7	13.0	2.8		
Baltimore	123	100	215	30.04	30.17	+0.13	50.4	+4.1	78	18	59	21	26	42	31	44	38	70	2.11	-0.4	8	9.5	s.	35	ne.	24	13	7	10	4.7	8.5	0		
Washington	112	62	85	30.04	30.17	+0.13	49.8	+4.6	79	18	60	14	27	40	36	42	38	75	2.60	+0.2	10	8.2	s.	36	nw.	14	15	8	7	4.3	7.0	0		
Cape Henry	18	8	54	30.15	30.17	+0.02	55.0	+2.9	81	18	62	28	29	48	25	51	49	84	2.86	+0.5	9	12.6	sw.	45	nw.	25	14	10	6	4.2	T	0		
Lynchburg	686	144	184	29.44	30.19	+0.06	50.6	+3.4	80	12	62	19	26	39	41	43	38	73	2.70	+0.4	7	6.7	nw.	29	sw.	18	13	8	9	4.3	3.0	T		
Norfolk	91	80	125	30.09	30.19	+0.10	55.6	+4.2	82	18	64	27	25	47	27	50	46	79	3.19	+1.0	10	10.0	s.	38	n.	25	12	9	9	4.5	4.0	0		
Richmond	144	11	52	30.03	30.19	+0.16	52.0	+3.7	79	6	64	19	28	40	38	45	41	78	3.61	+1.4	9	7.7	sw.	24	sw.	18	16	8	6	3.6	9.2	0		
Wytheville	2,304	49	55	30.19	30.19	+0.00	45.4	+2.4	73	2	57	13	28	34	39	---	---	---	3.92	+1.8	11	6.7	w.	22	w.	---	---	---	15	4	11	---	2.6	T
South Atlantic States																																		
Asheville	2,253	89	104	27.81	30.20	+0.06	48.8	+3.7	76	6	61	15	28	36	37	42	37	73	4.85	+2.6	9	9.3	nw.	31	se.	4	18	5	7	3.8	1.1	0		
Charlotte	779	63	86	29.33	30.18	+0.05	54.7	+4.1	79	2	64	22	28	45	32	48	42	68	3.12	+0.6	8	7.0	s.	21	sw.	24	15	3	12	4.5	T	0		
Greensboro	886	6	56	29.23	30.20	+0.07	51.0	+2.7	78	2	64	17	27	39	40	44	41	80	4.91	+0.6	8	7.6	sw.	24	sw.	14	14	6	10	4.3	T	0		
Hatteras	11	5	50	30.15	30.16	+0.01	60.1	+3.8	77	18	65	23	28	54	22	55	53	83	2.32	-1.2	10	13.1	n.	52	w.	24	14	8	8	4.6	0	0		
Raleigh	376	103	140	29.76	30.17	+0.04	54.6	+3.6	79	18	65	21	28	44	28	49	46	79	3.57	+1.3	8	8.6	sw.	29	nw.	8	13	9	8	4.6	2.8	0		
Wilmington	72	73	107	30.10	30.17	+0.07	58.4	+2.4	80	18	68	25	28	49	29	53	50	81	3.92	-1.0	7	8.7	ne.	32	nw.	25	15	6	10	4.3	0	0		
Charleston	48	11	92	30.11	30.16	+0.05	60.1	+2.8	81	18	68	26	28	52	32	54	49	72	3.95	-1.5	11	10.2	n.	33	w.	24	12	8	9	4.2	0	0		
Columbia, S. C.	347	70	91	29.79	30.18	+0.06	57.4	+3.4	80	6	67	23	28	48	32	50	46	71	2.44	+0.5	10	7.8	ne.	24	sw.	24	15	4	11	4.4	T	0		
Greenville, S. C.	1,040	70	78	29.65	30.16	+0.04	54.0	+4.4	79	1	64	21	28	44	32	47	41	69	3.11	-1.1	9	6.7	ne.	36	sw.	18	15	3	12	4.4	0	0		
Savannah	182	62	77	29.96	30.15	+0.19	58.0	+3.5	82	6	69	24	29	47	37	51	46	75	3.85	+1.4	11	5.4	nw.	31	ne.	24	16	6	10	4.5	0	0		
Jacksonville	65	73	152	30.08	30.13	+0.05	62.3	+3.8	85	8	72	29	28	53	33	56	53	81	1.09	-1.0	7	10.4	ne.	32	nw.	24	15	7	7	4.3	0	0		
Florida Peninsula	43	86	110	30.08	30.13	+0.05	64.1	+1.9	85	18	72	28	28	56	38	59	56	83	1.47	-1.5	9	8.4	ne.	27	ne.	9	8	11	11	5.6	0	0		
Key West																																		
Miami	21	10	64	29.98	30.01	-0.01	76.4	+2.1	86	10	81	60	28	72	12	71	69	82	3.13	+0.9	12	10.8	ne.	27	n.	8	15	9	5	4.2	0	0		
Tampa	25	124	168	30.00	30.03	-0.03	74.3	+2.5	83	15	80	46	28	69	26	68	66	79	1.76	-1.2	10	10.3	ne.	29	n.	30	11	15	4	4.7	0	0		
Titusville	35	88	197	30.05	30.09	+0.01	68.6	+1.7	86	5	77	34	28	60	29	62	60	83	7.0	-1.0	7	11.8	e.	29	e.	6	13	12	5	4.3	0	0		
East Gulf States	43	5	36	30.08	30.13	+0.05	69.2	+2.6	86	17	79	35	28	60	28	63	61	---	2.05	0	10	---	nw.											

TABLE 2.—Climatological data for Weather Bureau stations, November 1933—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths		Total snowfall	Snow, sleet, and ice on ground at end of month		
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. +2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch or more	Average hourly velocity	Prevailing direction	Maximum velocity				Date					
																								Miles per hour					Direction				
Ohio Valley and Tennessee																														0-10			
Chattanooga	762	71	214	29.34	30.17	+0.03	52.8	+2.4	78	13	64	20	28	42	33	45	39	67	5.21	+1.8	7	7.9	se.	31	se.	4	18	3	9	3.8	T	0.0	
Knoxville	995	66	84	29.09	30.17	+0.04	50.4	+2.5	78	7	62	18	28	38	34	43	38	72	4.68	+1.6	8	4.9	e.	25	w.	4	18	5	7	3.3	1.3	0.0	
Memphis	399	78	86	29.69	30.13	+0.01	52.9	+1.2	81	2	62	20	27	43	32	45	38	62	2.72	-1.5	7	8.9	s.	32	sw.	4	16	6	8	4.0	0.6	0.0	
Nashville	546	168	188	29.57	30.17	+0.05	50.0	+1.0	78	1	61	18	27	39	35	43	38	69	3.06	-0.4	10	9.3	s.	51	se.	4	17	5	8	3.8	1.5	0.0	
Lexington	989	6					46.8	+2.0	80	1	59	11	25	35	37				3.60	+0.3	11		s.				16	4	10		5.0	T	0.0
Louisville	525	188	234	29.55	30.12	.00	48.6	+1.9	78	2	59	13	27	38	35	42	36	68	3.13	-0.6	9	11.9	s.	45	se.	4	15	7	8	4.2	1.5	0.0	
Evansville	431	76	116	29.64	30.12	.00	49.1	+2.5	77	1	59	16	27	39	40	41	34	64	2.33	-1.4	8	11.0	s.	44	sw.	4	13	6	11	4.9	0.5	0.0	
Indianapolis	822	194	230	29.21	30.11	+0.01	45.7	+3.4	77	1	56	11	27	36	32	39	32	64	3.03	-0.3	10	8.7	s.	27	se.	4	11	11	8	5.1	4.9	0.0	
Terre Haute	575	63	149	29.45	30.08	.00	46.1		78	1	56	13	27	36	36	39	33	68	3.92	+0.6	10	11.2	sw.	43	se.	4	16	6	8	4.0	7.4	0.0	
Cincinnati	627	11	51	29.44	30.14	+0.02	47.3	+4.8	78	7	58	13	27	37	40	40	34	69	4.03	+1.2	10	8.9	s.	32	sw.	4	12	7	11	5.0	3.5	0.0	
Columbus	822	90	210	29.24	30.13	+0.02	45.4	+3.5	78	7	56	12	27	35	36	39	34	69	1.94	-0.8	11	10.8	s.	37	se.	4	11	7	12	4.8	1.7	0.0	
Dayton	900	186	213	29.14	30.11	+0.01	46.0	+4.0	76	7	56	12	27	36	37	39	33	68	4.68	+1.8	10	12.2	s.	38	se.	4	12	7	11	4.7	3.3	0.0	
Elkins	1,947	65	83	28.11	30.21	+0.09	43.3	+3.0	75	6	57	1	26	30	48	35	31	76	4.28	+1.6	11	6.2	se.	27	sw.	15	13	7	10	4.8	13.3	T	0.0
Parkersburg	637	77	84	29.45	30.15	+0.03	46.4	+2.6	82	7	54	15	25	34	39	39	35	75	2.92	+0.4	10	6.8	se.	30	nw.	13	15	7	8	4.5	8.5	T	0.0
Pittsburgh	1,273	39	54	28.88	30.14	+0.04	44.0	+2.8	78	7	54	15	28	34	37	37	31	68	2.64	+0.4	10	11.6	sw.	40	nw.	13	10	11	9	5.1	8.3	1.0	0.0
Lower Lake Region																														6.4			
Buffalo	768	243	280	29.25	30.10	+0.05	43.4	+3.6	73	4	51	14	25	36	30	38	34	74	3.79	+0.8	12	16.6	s.	49	w.	13	7	10	13	6.2	11.1	.2	0.0
Canton	448	10	61	29.60	30.09		37.2	+4.3	75	7	47	5	24	27	35	33	30	81	2.35	-0.8	11	9.3	sw.	30	w.	14	4	13	13	6.9	6.9	.6	0.0
Ithaca	836	77	100	29.21	30.13		41.3	+2.7	77	7	51	5	26	32	34	37	33	76	2.22	-1.1	12	9.4	se.	33	s.	8	6	4	20	7.3	6.6	.5	0.0
Oswego	335	71	85	29.73	30.10	+0.05	42.2	+3.3	78	7	51	11	26	34	32	37	33	74	2.34	-1.0	13	11.2	s.	31	w.	14	6	3	21	7.7	5.6	T	0.0
Rochester	523	86	102	29.53	30.12	+0.07	42.7	+4.0	77	7	51	11	25	34	32	37	32	70	2.10	-0.4	8	8.8	sw.	31	w.	14	8	7	15	6.6	7.2	.0	0.0
Syracuse	596	65	79	29.47	30.13	+0.07	43.0	+4.3	79	7	52	6	26	34	31				2.74	-0.0	12	8.3	s.	22	s.	8	6	6	16	6.6	9.8	.0	0.0
Erie	690	57	81	29.31	30.10	+0.04	45.2	+3.8	77	7	53	21	28	38	36	39	34	71	3.89	+0.6	11	10.6	sw.	28	w.	14	12	4	14	5.7	8.7	2.0	0.0
Cleveland	762	267	318	29.26	30.09	+0.02	46.6	+5.7	79	7	55	19	27	38	36	39	32	64	3.31	+0.7	10	17.1	s.	51	nw.	13	10	6	14	5.9	6.7	T	0.0
Sandusky	629	6	67	29.39	30.09	+0.01	44.8	+3.7	78	2	55	11	25	35	39				3.26	+0.9	11	10.4	s.	27	nw.	15	8	9	13	5.9	8.6	T	0.0
Toledo	626	70	87	29.40	30.10	+0.03	43.8	+3.4	76	2	53	12	27	35	36	37	31	68	1.75	-0.6	11	10.4	s.	28	w.	13	11	7	12	5.3	5.2	T	0.0
Fort Wayne	567	69	84	29.14	30.08	+0.02	42.8	+2.1	75	3	52	10	25	33	37	37	31	70	1.37	-1.5	9	10.7	s.	30	sw.	12	9	9	12	5.7	3.8	T	0.0
Detroit	626	5	78	29.38	30.08	+0.02	42.6	+3.3	75	3	52	12	27	34	37	37	33	74	1.22	-1.2	10	11.2	sw.	33	sw.	8	5	9	16	6.8	2.7	T	0.0
Upper Lake Region																														7.2			
Alpena	609	13	89	29.32	30.00	-0.01	39.2	+4.8	69	3	47	18	27	32	29	35	31	77	1.09	-1.5	11	12.6	s.	38	se.	16	2	10	18	7.4	4.9	.8	0.0
Escanaba	612	41	49	29.30	29.98	-0.05	35.6	+2.5	61	5	42	7	25	30	24	32	28	75	1.34	-0.8	11	12.7	nw.	37	n.	7	2	8	20	8.1	4.8	1.1	0.0
Grand Rapids	707	70	244	29.25	30.03	-0.02	43.0	+4.6	77	2	51	19	25	35	29	37	33	74	1.46	-1.3	9	13.6	s.	47	sw.	8	4	8	18	7.4	5.6	T	0.0
Lansing	878	5	90	29.09	30.05	-0.04	41.2	+3.7	76	2	51	13	27	31	35	35	31	74	.39	-2.1	7	10.4	s.	28	s.	7	5	10	15	6.6	7.4	.0	0.0
Marquette	734	44	69	29.13	29.93	-0.09	34.4	+1.1	68	2	40	10	25	28	23	32	29	83	2.96	-0.0	15	8.9	s.	26	sw.	28	0	4	26	8.8	21.4	2.0	0.0
Sault Sainte Marie	614	11	52	29.28	30.00	-0.01	35.6	+3.6	74	3	43	10	25	28	23	32	29	81	2.64	-0.0	18	9.7	se.	30	nw.	22	3	4	23	8.2	19.5	1.0	0.0
Chicago	673	7	131	29.30	30.04	-0.03	43.6	+3.5	76	2	51	16	26	36	27	38	32	67	1.95	-1.4	5	12.2	sw.	28	sw.	7	11	6	13	5.4	2.0	.0	0.0
Green Bay	617	109	141	29.30	29.98	-0.06	37.3	+3.3	72	3	43	10	25	31	24	33	28	72	1.50	-0.7	9	12.3	s.	34	w.	13	8	6	16	6.9	1.0	.0	0.0
Milwaukee	681	97	221	29.25	30.00	-0.05	40.9	+3.6	77	2	48	15	25	34	27	36	32	73	1.86	+1.8	8	13.9	w.	38	s.	5	9	7	14	6.0	9.0	.0	0.0
Duluth	1,133	5	47	28.70	29.95	-0.09	27.0	-3.0	64	2	34	-5	22	20	28	25	22	83	2.25	+0.8	11	13.4	nw.	36	nw.	22	6	6	18	7.4	6.7	3.7	0.0
North Dakota																														6.7			
Moorhead, Minn.	940	50	58	28.96	30.01	-0.06	24.2	-2.9	72	1	35	-10	15	14	35	22	20	83	.86	-0.0	10	8.9	nw.	26	n.	21	5	5	20	7.5	11.3	.5	0.0
Bismarck	1,677	8	57	28.18	30.03	-0.04	25.8	-2.7	52	9	35	-4	22	17	31	23	19	76	.81	+0.2	8	9.2	w.	30	nw.	13	5	11	14	6.5	8.1	.4	0.0
Devils Lake	1,478	11	44	28.37	30.00	-0.06	21.2	-3.3	58	1	31	-14	26	11																			

TABLE 2.—Climatological data for Weather Bureau stations, November 1938—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind													
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station reduced to mean 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. +2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 inch or more	Average hourly velocity	Prevailing direction	Maximum velocity			Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month	
																								Miles per hour	Direction	Date							
Middle Slope	ft.	ft.	ft.	in.	in.	in.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	in.	in.		Miles											
							41.6	-1.2										55	1.24	+0.2										0-10	in.	in.	
Denver	5,292	106	113	24.70	30.06	0.00	37.1	-2.7	65	9	49	9	26	26	36	26	18	52	1.27	+7	8	8.4	s.	26	n.	23	15	9	6	4.4	15.3		
Pueblo	4,685	80	86	25.29	30.06	+0.01	36.6	-2.8	68	4	52	-1	26	21	49	29	20	56	.41	-0	3	7.7	nw.	32	n.	16	15	10	6	3.9	5.1		
Concordia	1,392	50	58	28.54	30.05	+0.03	41.6	+1.2	75	2	54	6	24	30	37	34	26	61	1.72	+7	3	10.0	sw.	30	sw.	2	17	7	6	3.7	.8		
Dodge City	2,509	10	86	27.39	30.04	+0.03	41.5	-1.1	78	1	56	5	24	27	44	31	15	45	.07	-7	3	12.3	n.	33	s.	9	16	8	6	3.5	.2		
Wichita	1,358	85	93	28.60	30.06	+0.02	43.9	-0.9	73	2	54	11	24	34	32	37	28	56	2.05	+7	5	11.1	s.	30	s.	2	17	6	7	3.5	.2		
Oklahoma City	1,214	10	47	28.77	30.07	+0.01	48.6	-2.2	78	12	60	16	24	37	33	40	31	59	1.94	+1	4	11.5	s.	28	s.	2	16	10	4	3.4	1.9		
Southern Slope							50.6	-1.2										44	0.36	-0.7										2.6			
Abilene	1,738	10	56	28.26	30.09	+0.02	53.4	-1.1	86	17	66	18	24	40	39	41	29	46	.97	-4	3	11.0	s.	30	s.	2	18	8	4	2.9	.4		
Amarillo	3,676	10	49	26.28	30.05	+0.00	45.6	+1.1	76	11	69	13	24	32	39	34	20	43	.43	-5	3	10.1	sw.	27	nw.	17	22	4	4	2.5	T		
Del Rio	960	63	71	29.07	30.07	+0.02	58.4	-1.6	89	16	70	30	8	47	40	47	35	47	T	-1.2	0	9.6	se.	32	nw.	18	13	11	6	4.0	.0		
Roswell	3,566	75	85	26.42	30.07	+0.04	45.0	-3.1	78	5	62	7	24	28	55	34	17	38	.02	-8	1	8.0	s.	32	w.	12	26	4	1	1.8	T		
Southern Plateau							44.8	-3.6										39	0.20	-0.4										1.9			
El Paso	3,778	82	101	26.25	30.07	+0.07	49.8	-2.9	78	11	64	20	24	35	41	37	20	33	T	-5	0	7.5	w.	26	nw.	2	26	4	0	1.3	.0		
Albuquerque	5,314	5	39	25.10	30.10	+0.08	38.0	-5.3	71	1	54	7	24	22	44	25	13	42	.02	-4	2	7.7	n.	40	nw.	17	22	3	5	3.1	.1		
Santa Fe	7,013	38	53	23.24	30.11	+0.08	34.2	-4.7	57	1	46	7	23	28	26	12	44	1.09	+4	4	6.8	n.	25	nw.	17	23	2	5	2.7	11.5			
Flagstaff	6,907	10	59	23.37	30.07	+0.05	33.5	-1.1	62	16	49	1	13	18	46	25	83	.28	-1.2	2	10.1	nw.	35	nw.	17	14	14	2	2	1.2	.0		
Phoenix	1,107	39	51	28.88	30.04	+0.06	56.0	-3.7	79	1	72	31	13	40	41	42	26	36	T	-7	0	5.5	e.	20	nw.	2	25	4	1	1.5	.0		
Yuma	141	9	54	29.92	30.07	+0.09	59.0	-3.4	81	17	72	40	21	46	39	44	22	26	.00	-3	0	7.6	n.	27	n.	23	27	2	1	1.1	.0		
Independence	3,957	5	26				42.9	-4.3	67	17	57	16	13	29	38	34	10	.01	-3	1		nw.				37	3	0			T		
Middle Plateau							33.6	-5.3										60	0.24	-0.4										3.7			
Reno	4,527	61	76	25.60	30.22	+0.11	37.6	-3.9	64	8	51	11	12	24	30	31	22	56	.19	-4	2	5.9	w.	26	sw.	4	19	7	4	2.9	.4		
Tonopah	8,090	12	20				37.1		57	4	45	10	12	29	24	30	21	58	.05		3		nw.								.6		
Winnemucca	4,344	18	56	25.75	30.25	+0.11	32.2	-6.2	56	20	46	3	12	18	41	27	19	59	.34	-3	6	8.1	sw.	29	sw.	4	14	6	10	4.4	1.0		
Modena	5,473	10	48	24.70	30.17	+0.09	31.2	-5.2	68	20	45	1	13	17	48	25	18	63	.35	-2	3	9.0	w.	38	w.	1	19	7	4	2.9	4.1		
Salt Lake City	4,227	32	46	25.89	30.23	+0.11	32.4		56	20	42	13	25	23	29	28	24	72	1.48		8	8.0	sw.	41	nw.	1	14	8	8	4.6	1.8		
Grand Junction	4,602	60	68	25.48	30.14	+0.06	33.4	-5.9	59	1	45	10	25	22	34	27	18	54	.07	-5	4	5.5	n.	26	sw.	11	15	9	6	3.8	T		
Northern Plateau							36.1	-3.3										70	1.41	0.0										6.2			
Baker	3,471	36	54	26.58	30.25	+0.09	31.6	-4.4	50	2	40	8	23	23	29	29	24	75	.92	-1	12	5.8	s.	26	sw.	16	7	8	13	6.8	3.3		
Boise	2,739	79	87	27.35	30.28	+0.11	35.6	-5.4	54	19	44	15	23	27	26	32	29	70	2.51	+1.2	10	4.8	sw.	22	nw.	20	9	7	14	5.9	8.0		
Pocatello	4,466	5	31	25.58	30.23	+0.09	31.1		52	29	40	4	23	22	39	27	22	70	1.46		5	9.8	w.	34	w.	30	7	10	13	6.1	T		
Spokane	1,929	101	110	28.08	30.19	+0.09	35.1	-3.4	53	16	42	14	23	28	21	32	28	73	.89	-1.2	10	7.2	s.	24	sw.	3	7	7	16	6.5	1.2		
Walla Walla	1,991	57	65	29.12	30.22	+0.09	40.0	-2.8	62	7	47	19	23	34	26	36	30	68	2.44	+4	14	6.1	s.	27	sw.	16	7	10	13	6.5	4.2		
Yakima	1,078	58	67	29.02	30.20		38.2	-7.7	59	2	48	15	23	29	25	34	27	64	.31	-5	5	4.7	nw.	27	nw.	16	10	7	13	5.3	T		
North Pacific Coast Region							44.9	-0.9										74	4.52	-1.9										7.2			
North Head	211	11	56	29.92	30.16	+0.11	47.6	-6	57	25	52	33	10	43	13	44	36	74	6.51	-1.9	20	15.7	e.	58	s.	2	4	8	18	7.5	.0		
Seattle	125	90	321	30.01	30.15	+0.11	45.4		58	1	51	29	11	40	17	42	38	76	2.87	-2.2	14	10.0	s.	32	s.	3	6	8	16	7.0	1.4		
Tacoma	194	172	201	29.96	30.18	+0.14	44.0		57	30	50	28	11	38	18			74	3.29	-3.0	14	8.9	s.	36	sw.	3	9	5	16	6.6	T		
Tatoosh Island	86	10	54	30.01	30.11	+0.14	47.0	+1.1	58	26	50	37	11	44	12	43	38	70	7.46	-4.5	16	19.4	e.	50	e.	26	4	10	16	7.2	.0		
Medford	1,329	29	58	28.80	30.25	+0.10	42.0	-1.8	63	26	52	20	22	32	35	38	33	75	2.25	-2	10		nw.			4	11	15	6.7	.5			
Portland, Ore.	1,154	68	106	30.04	30.20	+0.14	44.8	-2.0	67	3	50	30	12	40	15	41	35	72	4.83	-1.3	15	7.0	sw.	21	sw.	3	3	9	18	7.7	T		
Roseburg	610	45	76	29.66	30.23	+0.11	43.7	-2.2	61	28	51	24	24	36	28	42	38	80	4.40	-1.3	15	3.9	s.	21	s.	29	2	10	18	7.7	.3		
Middle Pacific Coast Region							52.8	-1.0										59	1.63	-1.8										3.8			
Eureka	60	72	88	30.13	30.20	+0.00	48.8	-2.3	63	23	56	34	12	42	24	46	43	70	3.2	-2.1	9	6.8	sw.	27	nw.	1	12	8	10	4.9	.0		
Redding	722	20	34				53.4		76	25	63	32	11	44	30	43	29	44	1.63	-2.7	6	8.4	nw.	24	n.	21	13	8	9	4.5	.0		
Sacramento	66	92	115	30.07	30.14	+0.05	52.0	-1.6	72	17	64	30	12	40	32	44	34	54	.88	-1.0	4	6.3	n.	28	nw.	17	21	6	3	2.5	.0		
San Francisco	155	112	132	29.96	30.14	+0.05	56.8	+0.5	73	16	64	44	13	50	25	49	40	60	.88	-1.5	5	6.1	w.	21	se.	28	18	9	3	3.1	.0		
South Pacific Coast Region							58.5	+0.2										46	0.04	-0.9										2.3			
Fresno	327	97	105	29.78	30.14	+0.05	53.6	-0.6	76	27	66	29	12	41	35	45	33	49	.10	-8	4	4.7	nw.	18	nw.	11	18	10	2	2.6	.0		
Los Angeles	338	159	191	29.70	30.07	+0.05	62.7	+1.8	84	19	73	44	13	52	30	48	30	37															

TABLE 3.—Data furnished by the Canadian Meteorological Service, November 1938

Stations	Altitude above mean sea level. Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Depart- ure from normal	Mean max. + mean min. +2	Depart- ure from normal	Mean maxi- mum	Mean mini- mum	Highest	Lowest	Total	Depart- ure from normal	Total snowfall
	Feet	In.	In.	In.	°F.	°F.	°F.	°F.	°F.	°F.	In.	In.	In.
Cape Race, Newfoundland.....	99												
Sydney, Cape Breton Island.....	48	29.87	30.01	+0.05	41.7	+3.3	49.5	33.9	68	23	6.29	+1.21	7.4
Halifax, Nova Scotia.....	83	29.79	30.07	+0.08	43.0	+4.2	50.0	36.0	68	18	5.43	+0.20	4.1
Yarmouth, Nova Scotia.....	65	29.97	30.09	+0.09	42.8	+2.6	49.8	35.9	63	15	3.47	-0.57	10.4
Charlottetown, Prince Edward Island..	38	29.97	30.05	+0.11	39.0	+3.0	46.0	32.1	66	20	3.70	+0.31	16.0
Chatham, New Brunswick.....	28	29.92	30.03	+0.05	32.9	+0.7	42.3	23.5	69	1	3.04	-0.36	24.9
Father Point, Quebec.....	20	30.03	30.05	+0.09	29.8	+0.4	37.1	22.4	68	6	1.91	-1.43	7.1
Quebec, Quebec.....	296	29.73	30.07	+0.07	34.6	+4.9	40.8	28.4	71	4	3.76	+0.33	22.3
Doucet, Quebec.....	1,236	28.65	30.03	+0.03	25.0	+1.2	35.4	14.5	64	-32	3.80	+1.21	16.5
Montreal, Quebec.....	187												
Ottawa, Ontario.....	236	29.82	30.08	+0.06	34.3	+2.0	43.6	25.0	71	6	1.66	-1.04	4.7
Kingston, Ontario.....	285	29.78	30.10	+0.06	39.9	+3.5	46.7	33.1	66	9	1.77	-1.15	3
Toronto, Ontario.....	379	29.66	30.10	+0.05	41.2	+3.6	48.7	33.7	69	14	1.45	-1.31	1.7
Cochrane, Ontario.....	930	28.92	29.98	-0.02	22.2	-1.2	30.5	14.0	68	-17	3.82	+1.72	28.2
White River, Ontario.....	1,244	28.58	29.98	-0.01	20.2	-2.5	31.3	9.0	57	-33	5.39	+2.93	28.2
London, Ontario.....	808	29.20	30.10	+0.04	38.6	+1.8	48.0	29.1	69	10	2.42	-1.01	11.4
Southampton, Ontario.....	656	29.30	30.02	+0.00	39.6	+2.9	47.5	31.8	72	8	1.64	-1.91	9.2
Parry Sound, Ontario.....	688	29.36	30.04	+0.03	38.2	+4.5	46.3	30.2	69	6	3.16	-0.92	19.5
Port Arthur, Ontario.....	644	29.24	29.96	-0.06	25.1	-2.1	32.8	17.3	63	-16	4.14	+2.62	14.9
Winnipeg, Manitoba.....	760	29.10	30.00	-0.09	18.8	-3.0	27.8	9.9	53	-14	.86	-0.22	7.7
Minnedosa, Manitoba.....	1,090	28.12	30.01	-0.04	18.5	-3.2	26.9	10.1	40	-15	.55	-0.35	3.6
Le Pas, Manitoba.....	860	28.97	29.99	+0.01	12.4	-5.0	21.6	3.3	46	-27	.52	-0.28	5.2
Qu'Appelle, Saskatchewan.....	2,115	27.64	30.00	-0.06	19.2	-3.2	27.7	10.8	42	-10	2.00	+0.99	11.6
Moose Jaw, Saskatchewan.....	1,759	27.95	30.00	-0.04	24.5	+0.3	31.9	17.1	50	3	.74	+0.12	5.9
Swift Current, Saskatchewan.....	2,392	27.04	30.02	-0.04	24.9	-1.2	33.2	16.6	47	-1	.43	-0.13	4.2
Medicine Hat, Alberta.....	2,365	27.44	30.00	-0.04	27.7	-2.3	37.0	18.3	58	-3	.76	+0.07	6.9
Calgary, Alberta.....	3,540	26.18	29.96	-0.10	27.4	+1.0	37.2	19.7	57	-12	1.07	+0.33	10.7
Banff, Alberta.....	4,521	25.26	29.98	-0.06	23.8	-0.1	32.0	15.5	41	-8	1.17	-0.28	11.7
Prince Albert, Saskatchewan.....	1,450	28.40	30.02	-0.02	18.2	-0.4	25.0	11.5	44	-11	1.81	+0.93	18.1
Battleford, Saskatchewan.....	1,592	28.20	30.02	-0.02	17.8	-2.4	25.9	9.6	38	-8	1.44	+0.90	14.4
Edmonton, Alberta.....	2,150	27.64	30.02	+0.03	22.4	-3.3	29.7	15.2	46	0	1.16	+0.47	11.6
Kamloops, British Columbia.....	1,262	28.79	30.08	+0.06	34.7	-0.9	40.7	28.7	57	15	.65	-0.27	3.2
Victoria, British Columbia.....	230	29.89	30.15	+0.09	43.8	-0.8	47.8	39.7	55	31	2.96	-2.11	T
Barkerville, British Columbia.....	4,180												
Estevan Point, British Columbia.....	20												
Prince Rupert, British Columbia.....	170												
St. George's, Bermuda.....	158		30.16	+0.11	72.4	+4.2	77.3	67.5	83	60	3.90	-1.01	.0
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Kamloops, British Columbia.....	1,262	28.69	30.05	+0.02	50.2	+2.6	60.1	40.2	76	29	0.55	-0.10	0.0
Estevan Point, British Columbia.....	20	29.93	29.95	-0.04	52.0	+2.2	57.9	48.0	67	38	12.47	+1.07	.0

TABLE 4.—Severe local storms, November 1938

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as has been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Minneapolis-St. Paul, Minn., and vicinity	1	9:12 p. m.			\$500	Thundersquall	Property damaged.
Minnesota, south-central counties	2	4:30-11:25 p. m.			10,000	do	Do.
Nashauk, Minn., and vicinity	2	5:30 p. m.	67	0	20,000	Tornado, rain and hail	Farmhouse and buildings demolished; 1 person injured; path 32 miles long. The area through which this tornado passed was a sparsely settled forested area, otherwise the loss would have been greater.
Cherokee and Ingersoll, Okla.	2	6:30-7:30 p. m.	12		55,000	Wind and hail	Property damaged; path 12 miles long.
El Reno, Okla.	2	7 p. m.	13		5,000	Hail	Property damaged; path 8 to 10 miles long.
Sagerton, Tex.	2	10:30 p. m.	300	1	1,000	Tornado	2 persons injured; property damaged.
Wisconsin, northern portion	2	P. m.				Electrical and wind	The power house of the Superior Water, Light and Power Company struck by lightning. Superior plunged into darkness for several hours.
Wichita, Kans.	2-3					Wind, rain, electrical	4 persons injured; streets and several business houses flooded; wires down; several minor motor accidents reported. House struck by lightning and damaged; 2 women knocked unconscious by the bolt and 2 other occupants dazed. Large barn destroyed by lightning.
Lennox, S. Dak.	3	5:30 p. m.		0	5,000	Tornado	Several barns and garages moved from their foundations; 5 empty box cars destroyed; trees uprooted; path narrow.
Sioux Falls, S. Dak., eastern portion	3	6:05-6:45 p. m.			10,000	Wind and rain	Property damaged; interior of buildings ruined by driving rain.
Harrisburg, Ill.	4	12 noon				Wind	Radio tower blown down; broadcasting delayed.
Charenton, La.	4	2-2:30 p. m.	100	1	3,000	Tornado	3 persons injured; loss to crops; property damaged.
Park County, Ind.	4	P. m.			3,000	Wind	Damage to houses and barns.
Terre Haute, Ind.	4	do		1	2,000	do	Roofs blown off; trees uprooted; power and telephone lines down; damage in thousands of dollars.
Illinois, central and southern portions	4			1	170,550	do	11 persons injured; \$167,600 property damage; \$11,950 loss to crops.
Evansville, Ind.	4					Wind and dust	Portions of the slate roof of the filtration plant blown off; strips of roofing torn from a church; parked car damaged by falling tree; numerous signs blown down; plate glass windows blown in; section of the railroad gate across Fulton Avenue, at the Union Station, blown off; dust blown through closed windows into houses.
Dubuque, Iowa	7					Snow	Shrubby and trees damaged; motor travel difficult.
Anastasia Island, Fla.	8				88,500	Squalls	No damage to shipping reported; wind and wave erosion considerable on the east Florida coast. Amount estimated, damage on Anastasia Island, in the St. Augustine area, alone.
Bucyrus, Ohio	13					Wind	Several barns unroofed with damage of several thousand dollars.
Cheyenne, Wyo., and vicinity	15	6:45 p. m.			25,000	do	Wall of a hangar blown down demolishing 2 planes and damaging another.
Buffalo, N. Y., and vicinity	15					Snow, electrical	A heavy layer of clouds blocked out the sun at 1 p. m., causing night-time darkness. An electrical storm accompanied the darkness, with snow flurries, resulting in extremely poor visibility. Airplane flights canceled.
Pulaski, N. Y.	15					Snow	Several persons injured because of poor visibility and icy roads; traffic delayed.
Rogers, Ark., 7 miles northeast	17	P. m.	880	0	500	Tornado	3 homes damaged; trees uprooted; path 5 miles long.
Selma, Ohio, vicinity of	18	6:45 a. m.				Thundersquall	Farm property damaged.
Mound, La.	18	9:30 a. m.	200	0	3,000	Tornado	5 tenant houses demolished; 8 cars of a freight train overturned.
Vicksburg, Miss., 5 miles north	18	do			500	Thundersquall	Property damaged.
Krotz Springs, La.	18	9:45 a. m.	70	0	2,500	Tornado	7 persons injured; no details.
Stark and Mahoning Counties, Ohio	18	A. m.				Electrical	Property damaged.
Centerville to Auburn, Miss., and vicinities	18		440	1	4,500	Tornado	Property damaged; path 20 miles long.
Tennessee	23-24					Snow	Travel on most highways dangerous.
Washington, D. C., and vicinity	24-25			5		Snow and sleet	In Washington, D. C., 6.4 inches of snow fell, the greatest 24-hour fall and the largest monthly snowfall ever recorded here in November. Many accidents, with 2 deaths in Washington and 3 in nearby Virginia.
New England	24-25			19		Snowstorm	Hundreds of automobiles snow-bound on highways; bus and train service and shipping delayed; planes grounded.
Sandy Hook, N. J.	24-25					Snow and wind	6.5 inches of snow fell, greatest amount ever recorded here for November. Sleet formed on streets and all exposed surfaces, causing dangerous traffic conditions.
New York State	24-25			13		Snow and ice	10.0 inches of snow recorded, delaying motor traffic. 20 persons forced to sit in an Albany-New York bus for 7 hours when the machine struck a drift near Selkirk.
Baltimore, Md., and vicinity	24-25					Snow	8.5 inches of snow recorded; Chesapeake Bay shipping completely tied up.
Harrisburg, Pa.	24-25					Snowstorm	This storm occurring as it did on Thanksgiving Day, very seriously hampered the holiday motor traffic and, in some cases, tied it up. During the night an increasing wind drifted the snow reducing visibility to zero.
Lynchburg, Va.	24-25					Glaze	Ice formed on foliage, wires, and all exposed objects from 2:30 to 5 p. m. of the 24th, and remained until the middle of the morning of the 25th.
Pangburn, Ark.	25	A. m.			500	Wind	Farm buildings damaged; 1 person injured.

<sup>1</sup> Miles instead of yards.

U. S. GOVERNMENT PRINTING OFFICE: 1939

MONTHLY MEAN TEMPERATURE

TABLE 1. - Mean Temperature of the Air, Surface of the Water, and at Various Depths, and Direction and Force of the Wind, and State of the Sky, and Amount of Precipitation, for the Month of November, 1938.

Day	Time	Air	Surface of Water	At Various Depths	Direction and Force of the Wind	State of the Sky	Amount of Precipitation
1	0000	50.0	50.0	50.0			
1	0600	48.0	48.0	48.0			
1	1200	52.0	52.0	52.0			
1	1800	50.0	50.0	50.0			
2	0000	48.0	48.0	48.0			
2	0600	46.0	46.0	46.0			
2	1200	50.0	50.0	50.0			
2	1800	48.0	48.0	48.0			
3	0000	46.0	46.0	46.0			
3	0600	44.0	44.0	44.0			
3	1200	48.0	48.0	48.0			
3	1800	46.0	46.0	46.0			
4	0000	44.0	44.0	44.0			
4	0600	42.0	42.0	42.0			
4	1200	46.0	46.0	46.0			
4	1800	44.0	44.0	44.0			
5	0000	42.0	42.0	42.0			
5	0600	40.0	40.0	40.0			
5	1200	44.0	44.0	44.0			
5	1800	42.0	42.0	42.0			
6	0000	40.0	40.0	40.0			
6	0600	38.0	38.0	38.0			
6	1200	42.0	42.0	42.0			
6	1800	40.0	40.0	40.0			
7	0000	38.0	38.0	38.0			
7	0600	36.0	36.0	36.0			
7	1200	40.0	40.0	40.0			
7	1800	38.0	38.0	38.0			
8	0000	36.0	36.0	36.0			
8	0600	34.0	34.0	34.0			
8	1200	38.0	38.0	38.0			
8	1800	36.0	36.0	36.0			
9	0000	34.0	34.0	34.0			
9	0600	32.0	32.0	32.0			
9	1200	36.0	36.0	36.0			
9	1800	34.0	34.0	34.0			
10	0000	32.0	32.0	32.0			
10	0600	30.0	30.0	30.0			
10	1200	34.0	34.0	34.0			
10	1800	32.0	32.0	32.0			
11	0000	30.0	30.0	30.0			
11	0600	28.0	28.0	28.0			
11	1200	32.0	32.0	32.0			
11	1800	30.0	30.0	30.0			
12	0000	28.0	28.0	28.0			
12	0600	26.0	26.0	26.0			
12	1200	30.0	30.0	30.0			
12	1800	28.0	28.0	28.0			

Chart 1. Departure (°F.) of the Mean Temperature from the Normal, November 1938



Chart I. Departure (°F.) of the Mean Temperature from the Normal, November 1938

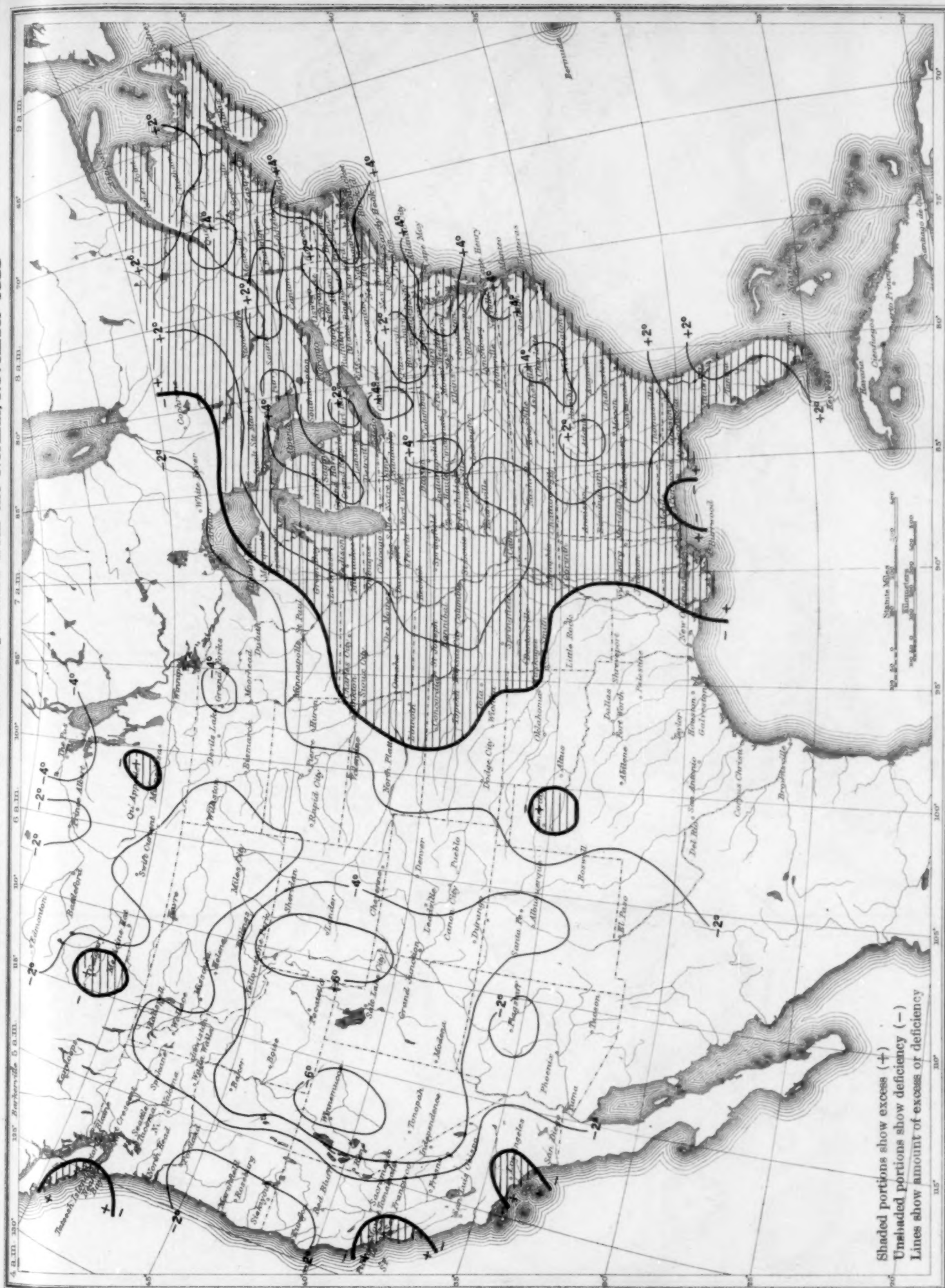
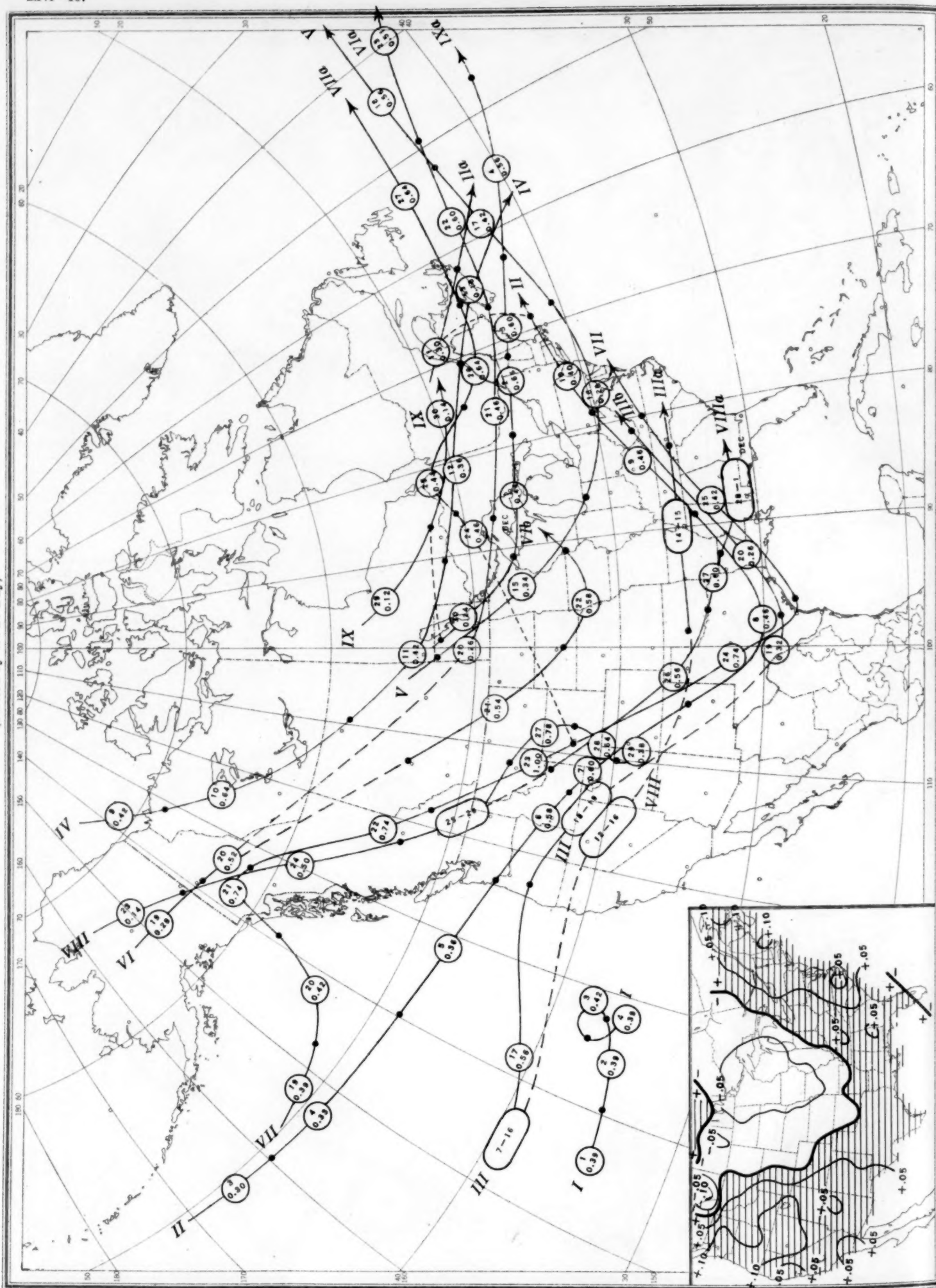


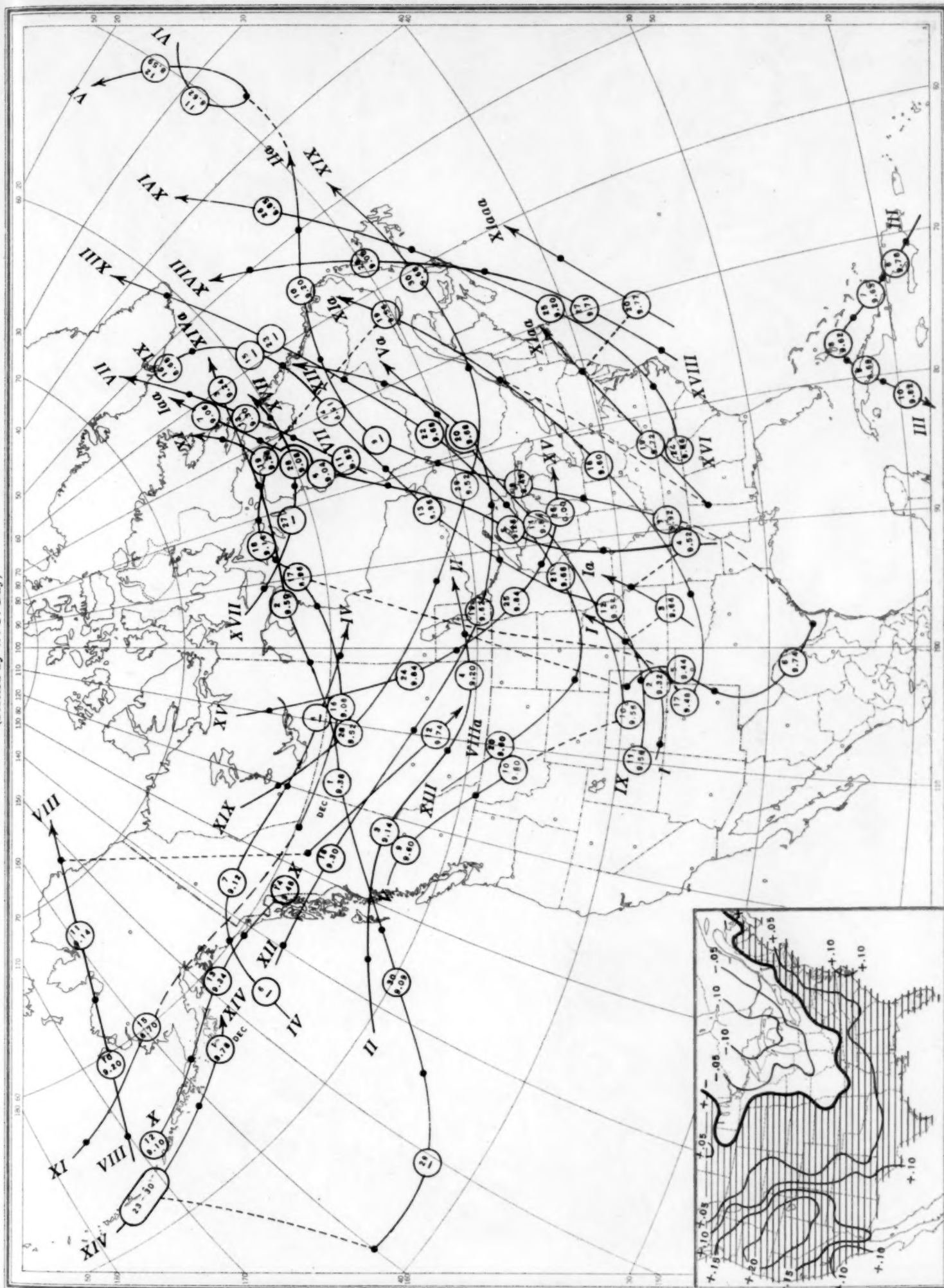
Chart II. Tracks of Centers of Anticyclones, November 1938. (Inset) Departure of Monthly Mean Pressure from Normal  
(Plotted by W. F. Day)



Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, November 1938. (Inset) Change in Mean Pressure from Preceding Month

Chart III. Tracks of Centers of Cyclones, November 1938. (Inset) Change in Mean Pressure from Preceding Month (Plotted by W. P. Day)



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, November 1938

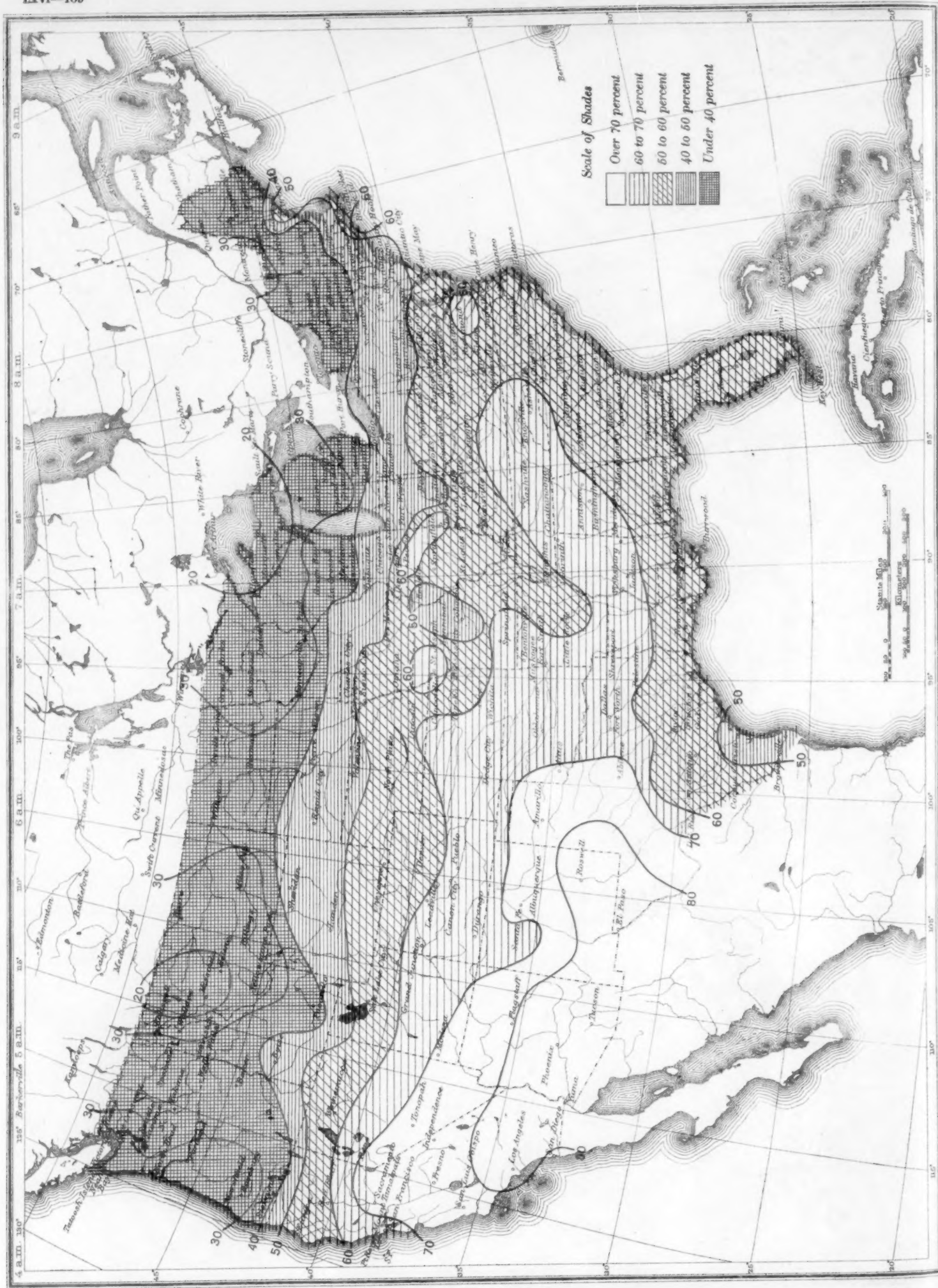


Chart V. Total Precipitation, Inches, November 1938. (Inset) Departure of Precipitation from Normal

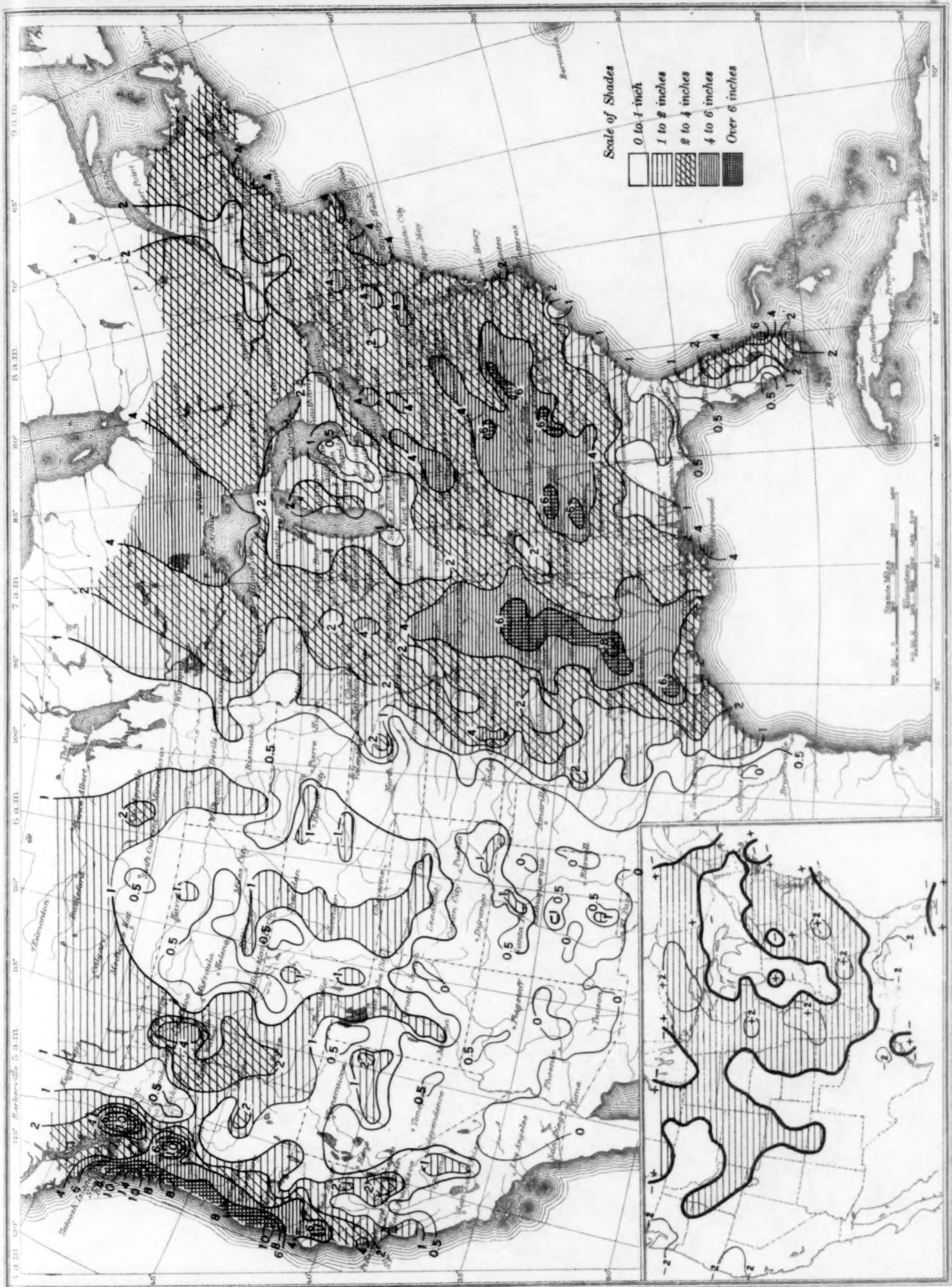


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, November 1938

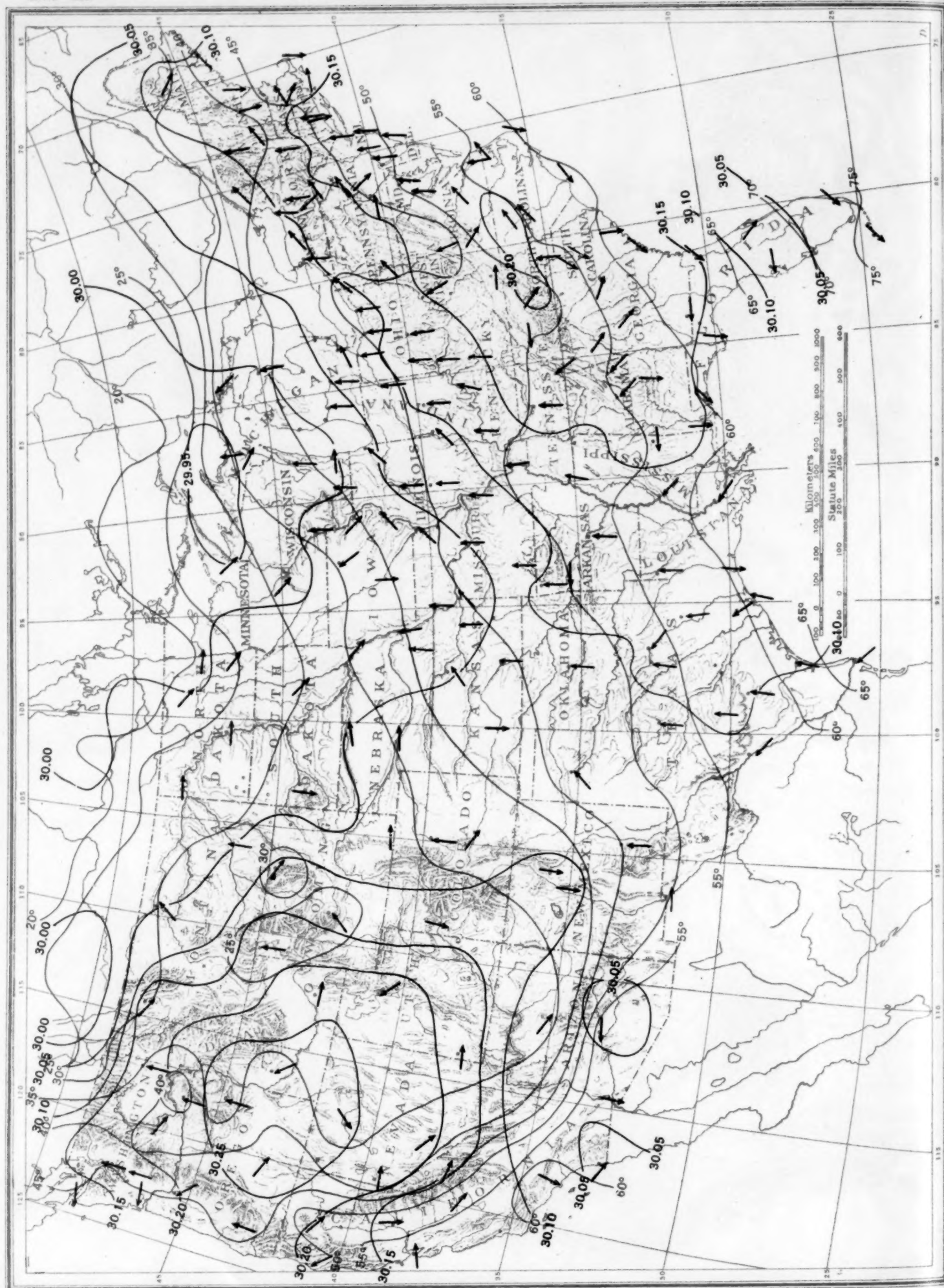


Chart VII. Wind Roses for Selected Stations, November 1938  
(Plotted by J. P. Kohler)

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(Plotted by J. F. Kohler)

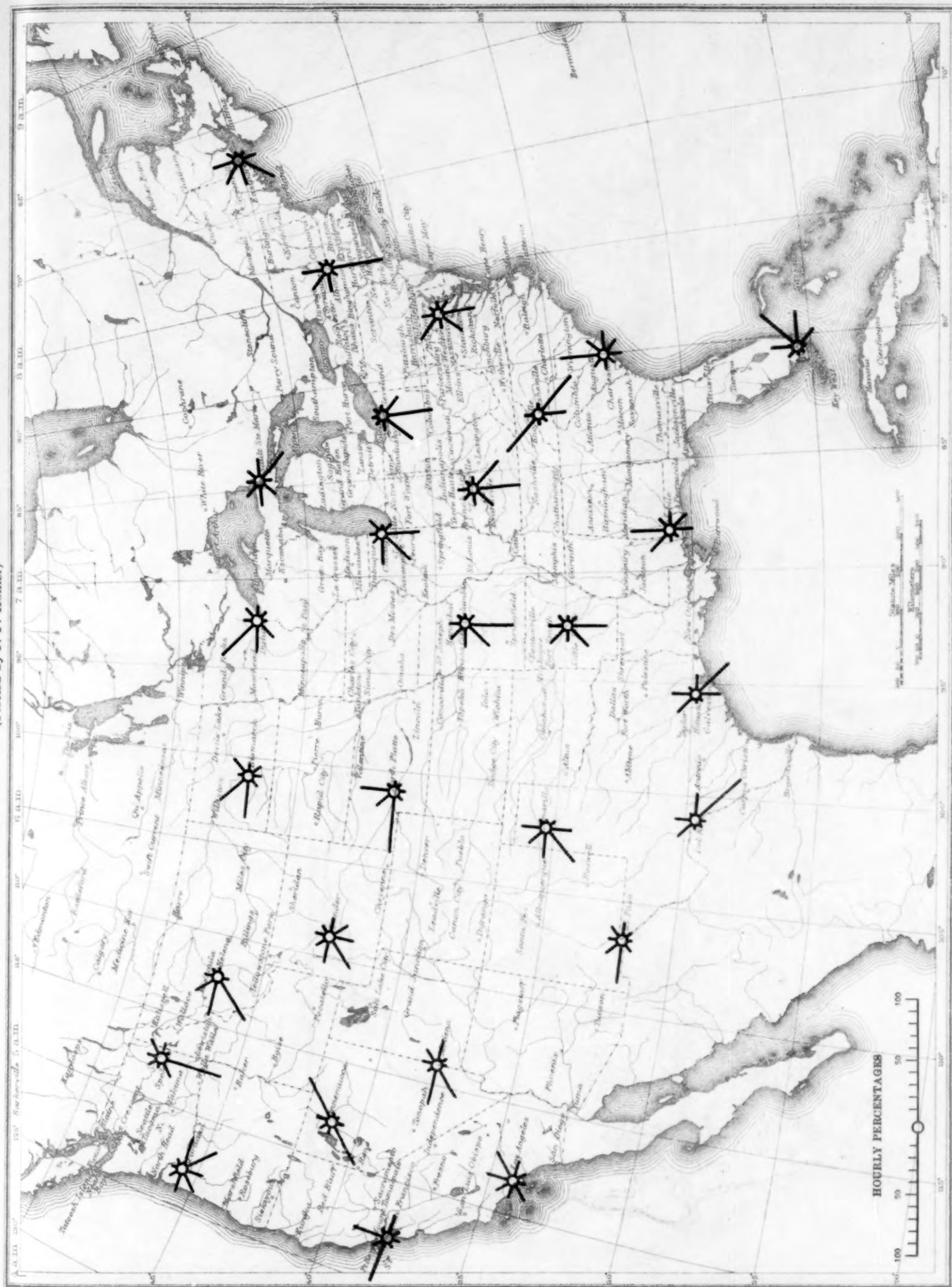


Chart VIII. Total Snowfall, Inches, November 1938

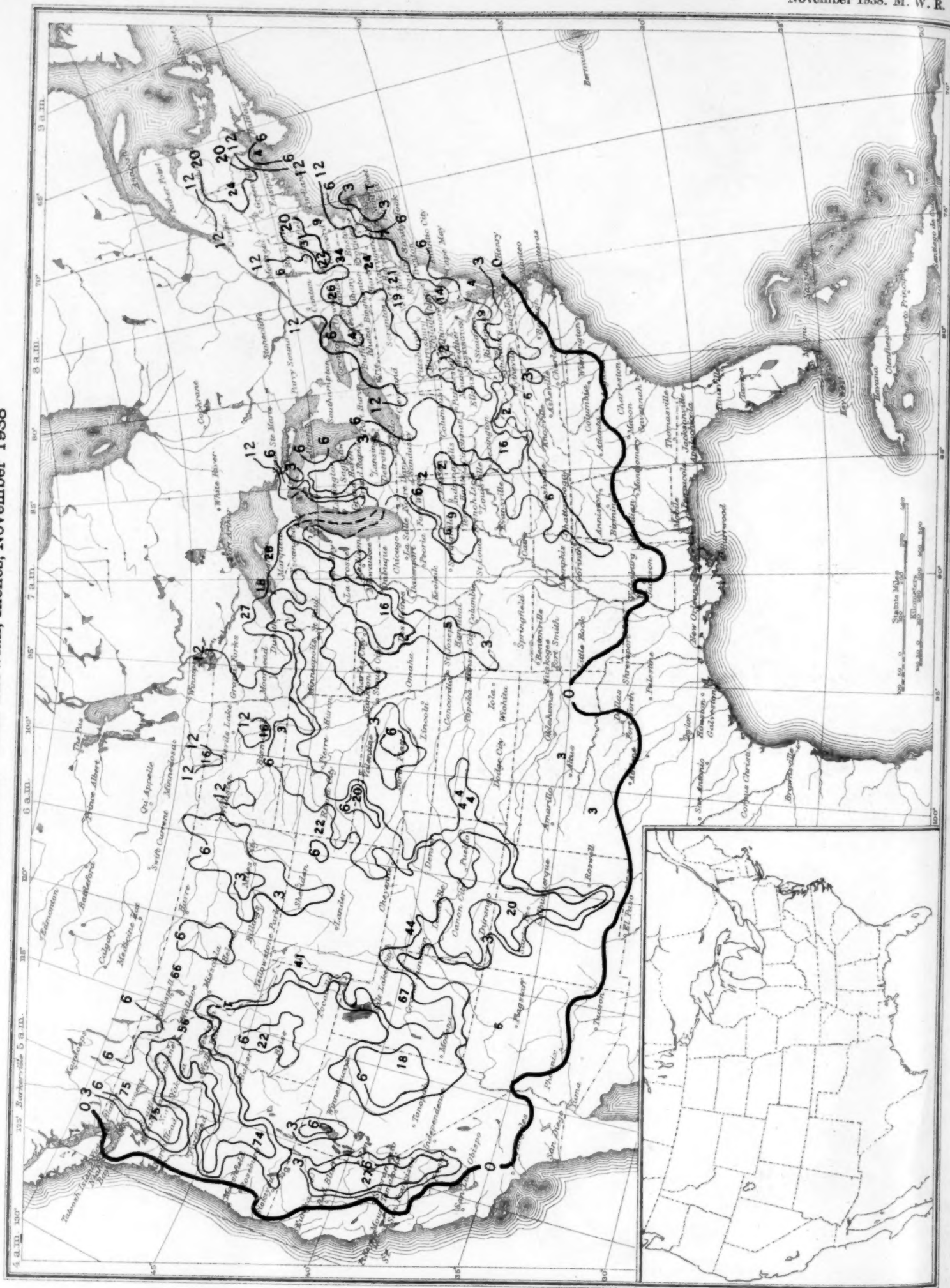


Chart IX. Weather Map of North Atlantic Ocean, November 8, 1938  
(Plotted from the Weather Bureau Northern Hemisphere Chart)

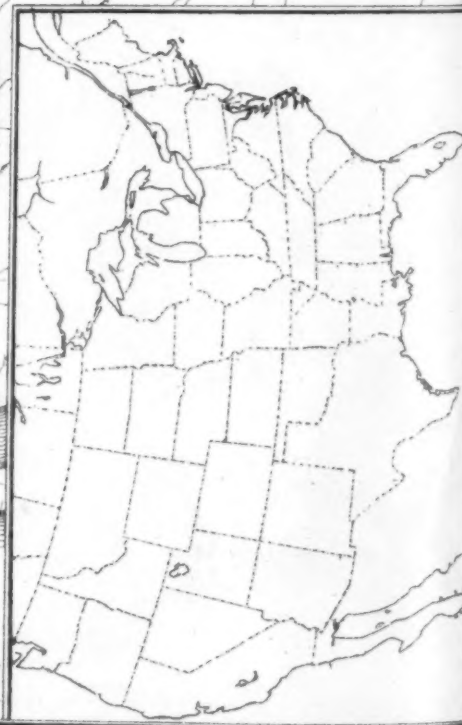
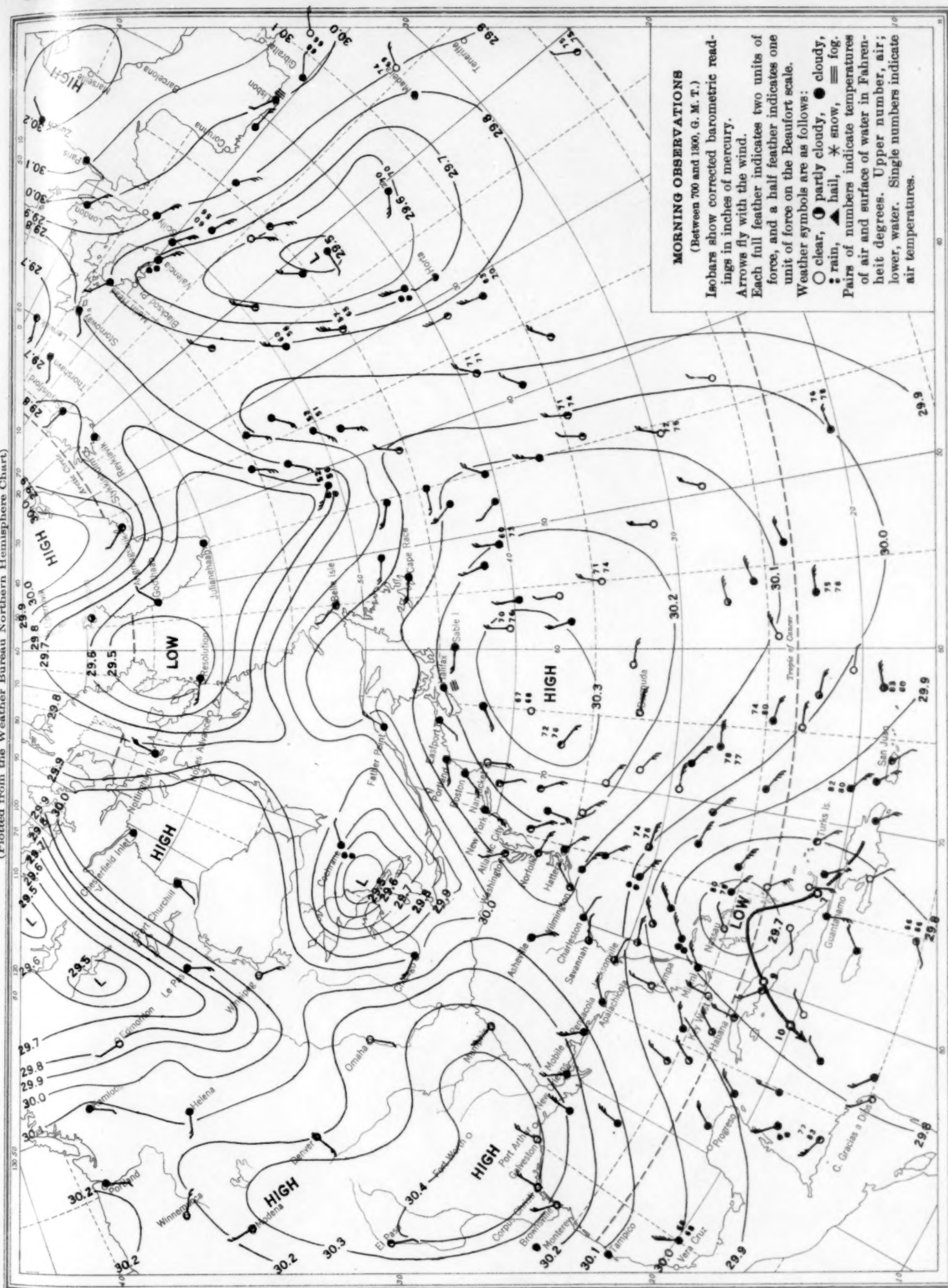


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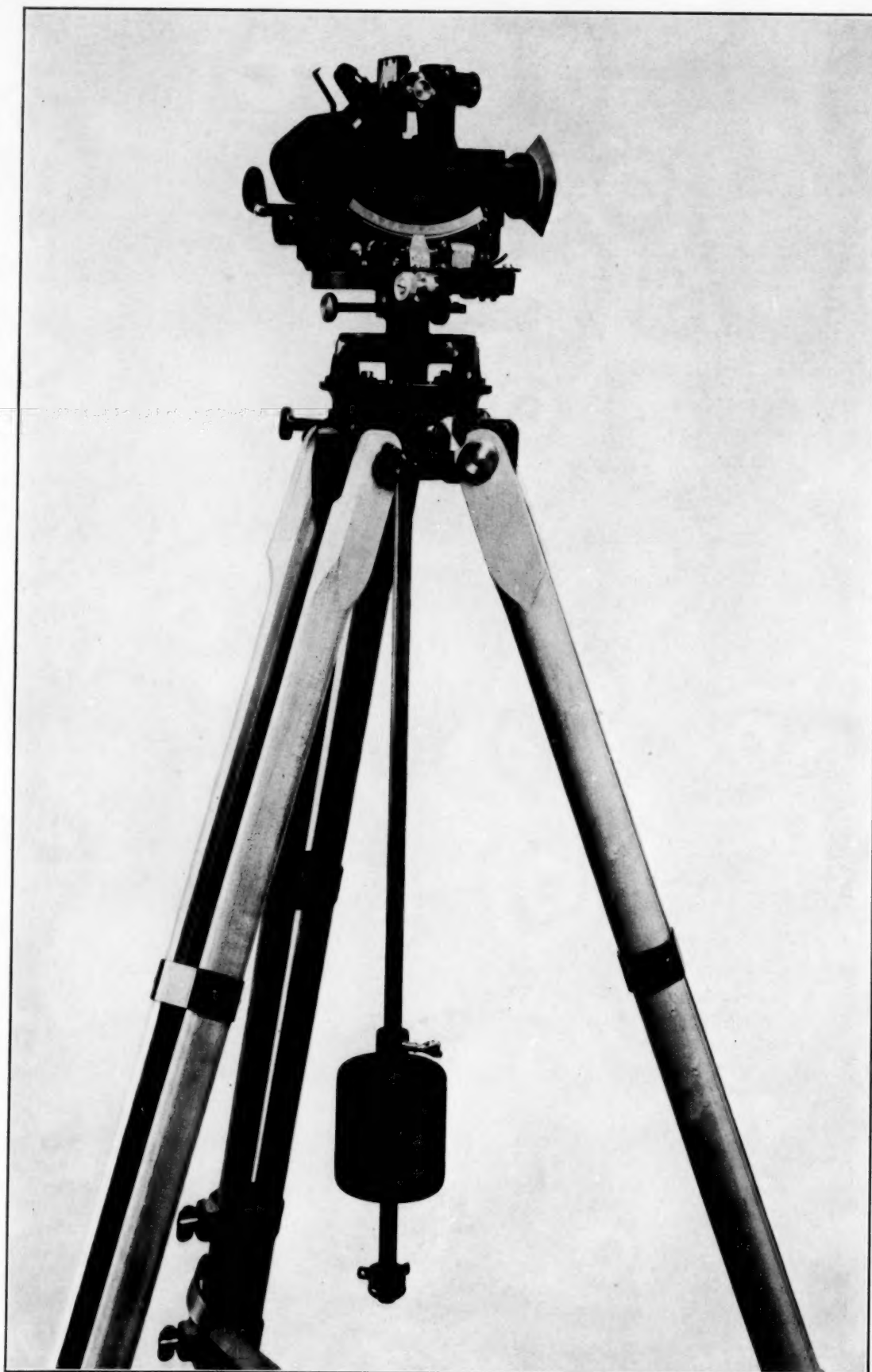


FIGURE 1.